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GENERAL ELECTRIC Review

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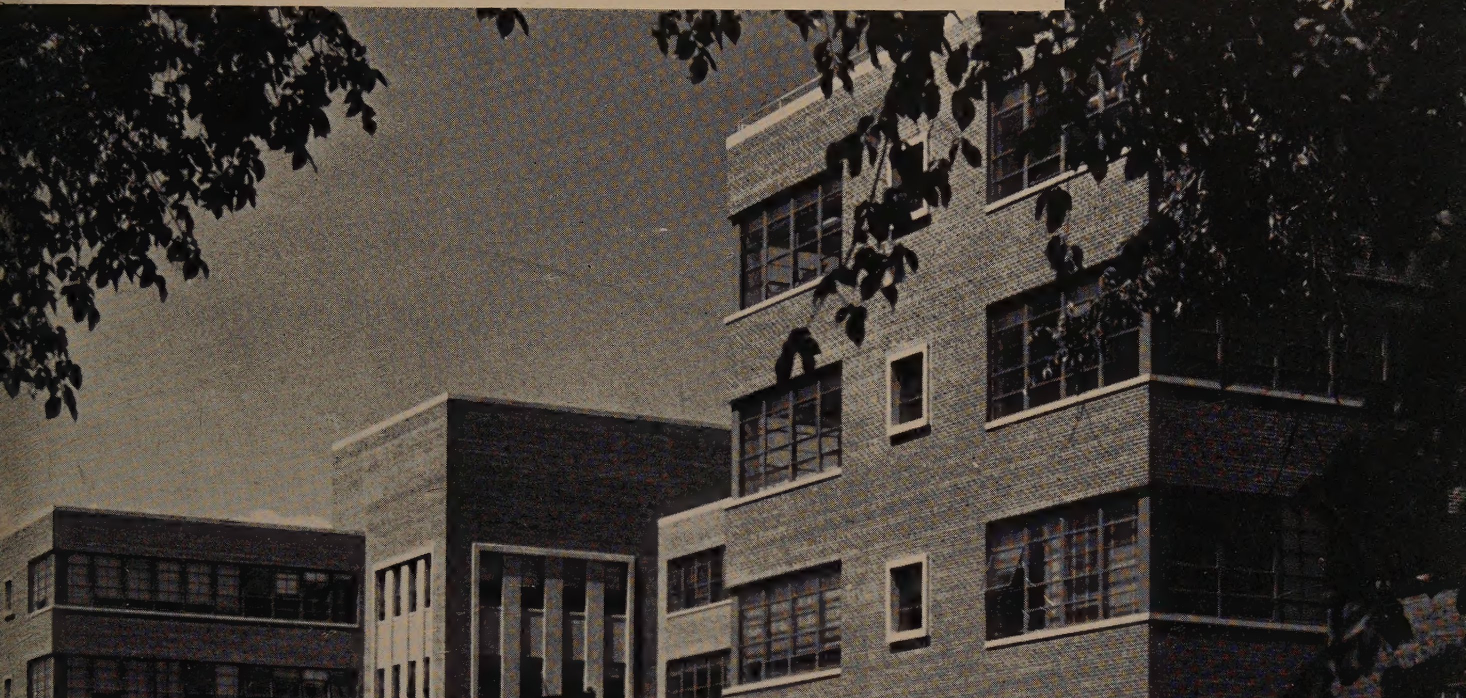

MEASUREMENTS

November 1950

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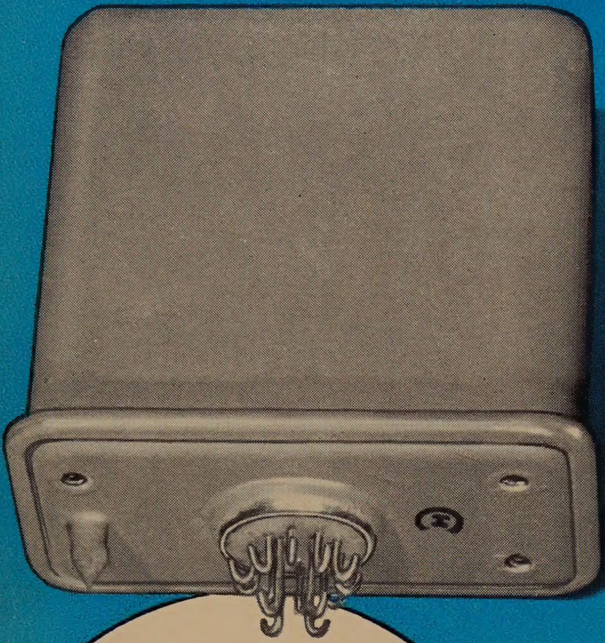

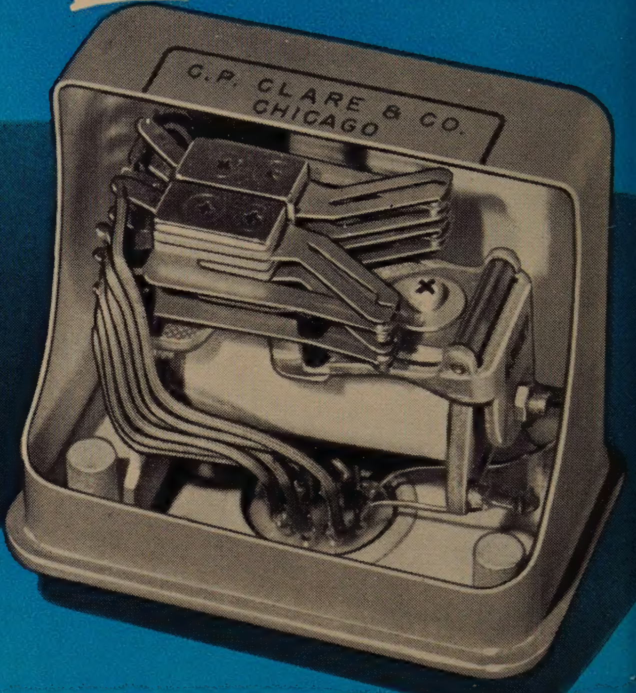

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CLARE RELAYS

. . . First in the Industrial Field

GENERAL ELECTRIC Review

NOVEMBER 1950
Vol. 53, No. 11

J. S. SMITH
Manager

E. C. SANDERS
Executive Editor

J. E. GLICK
Associate Editor

THE COVER

This illustration of the new Measurements Laboratory of General Electric's Meter and Instrument Divisions at West Lynn (Mass.) appropriately introduces the subject of this special issue of the REVIEW. As described in the article on p. 12, this ultra-modern laboratory provides optimum facilities for specialists in the fields of measurement and removes all physical barriers from the coordination and integration of their work in expanding and developing those fields. The variety and utility of measurements is typified by the other articles in this issue.

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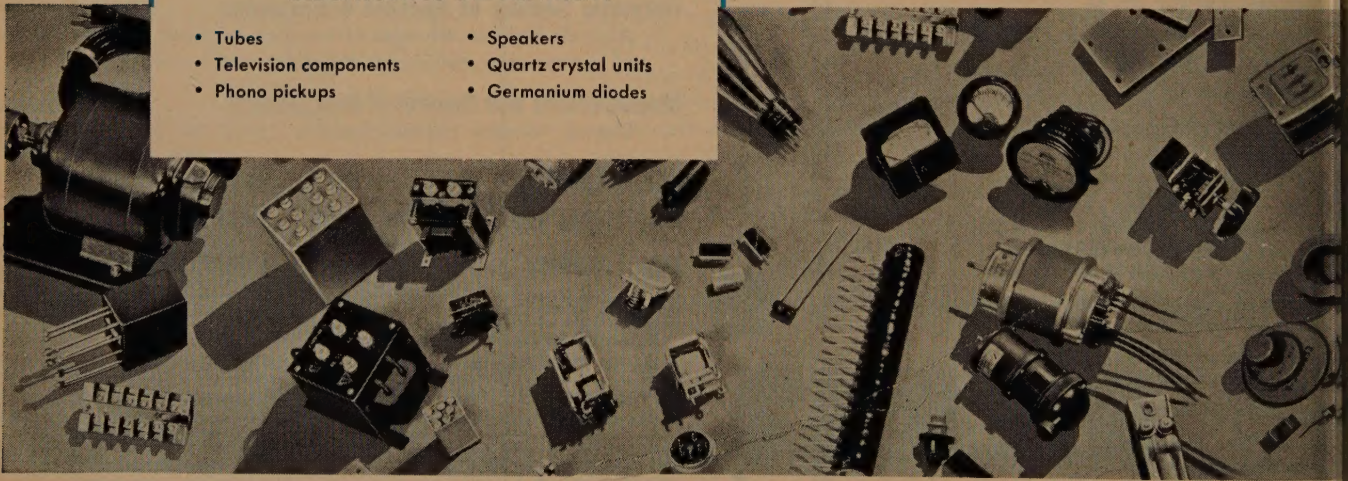

GENERAL ELECTRIC

667-8

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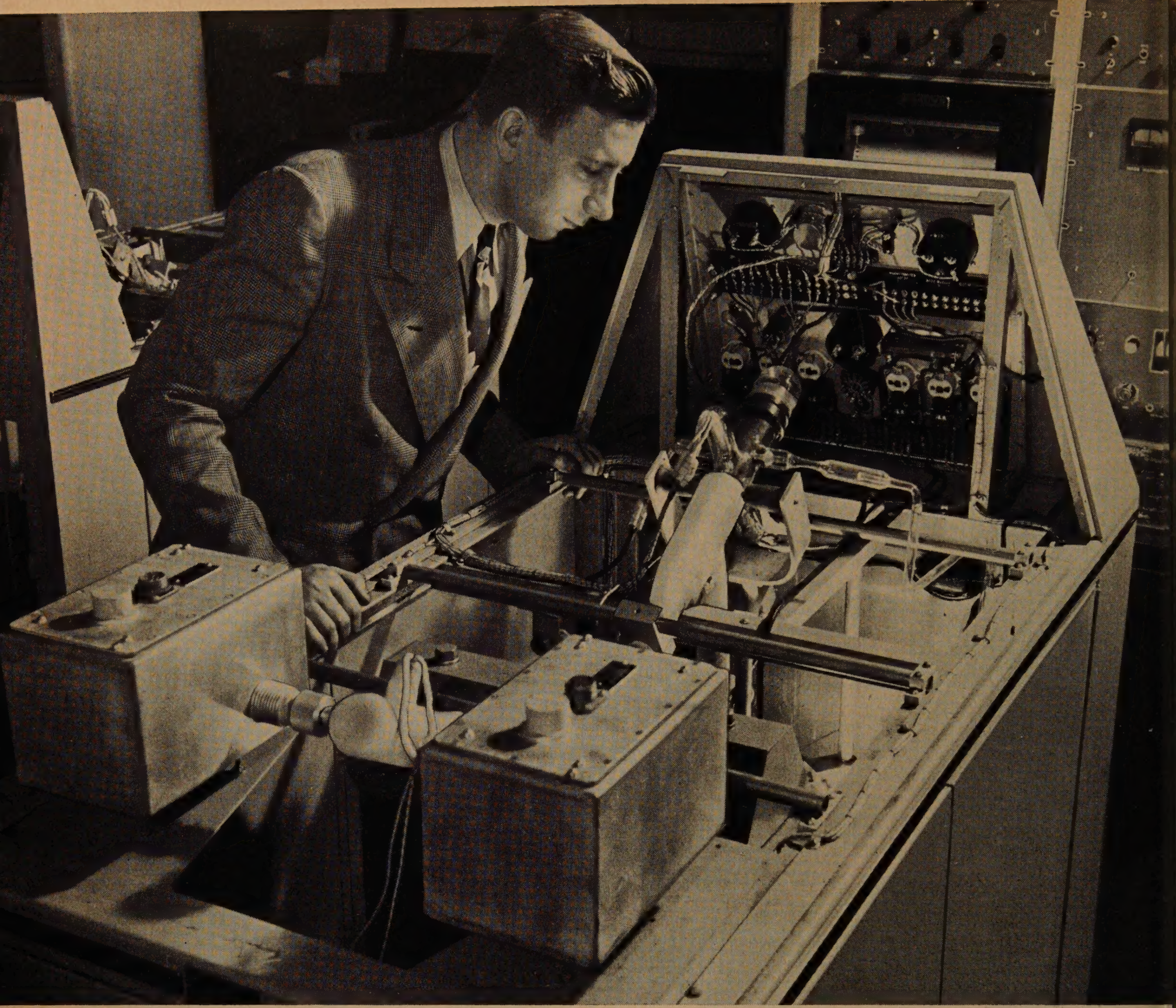

FOR ANALYZING GASES BY SPECTROMETRY

Measurements of impurities in gas streams, certain analytical work in the rubber and petroleum industries, and other types of gas analysis are among the many applications of recording mass spectrometers of the latest type, one of which is shown here being inspected in the laboratory

GENERAL ELECTRIC Review

Vol. 53 NOVEMBER 1950 No. 11

WITH BETTER FACILITIES TO TRANSFORM SCIENTIFIC VISIONS INTO REALITIES

By H. E. STRANG

Manager, Meter and Instrument Divisions, Apparatus Department
General Electric Company

"I do believe we shall continue to grow, to multiply and prosper until we exhibit an association powerful, wise, and happy beyond what has yet been seen by men . . . ."

Thomas Jefferson, third President of the United States and author of the Declaration of Independence, wrote those words in a letter to his friend, John Adams.

They could very well have been written by Professor Elihu Thomson, renowned scientist who many times voiced similar thoughts to his secretary, John McManus.

How true the words! How clear the vision!

The brilliant progress of the Thomson-Houston Company and, later, the General Electric Company, of which it was a major predecessor, under the engineering leadership of Professor Thomson is a matter of historical record.

His basic contributions to the science of electricity were many and cover the whole gamut of its various acets. But he invariably returned from the many detours imposed upon him by the roving inquiry of his cientific mind to the field of Measurements, in which he was extremely interested and which he knew to be o essential to the growth of the company and to the ndustry.

He and his associates provided many valuable nventions for electrical measuring devices, some of which are still used today.

It is upon many of these basic developments that we f the Meter and Instrument Divisions, who follow, ave continued to build and grow in the specialized lectrical measurements field.

Even as Thomson, Edison, Westinghouse, and others tood upon the threshold of a new era in the 1880's, ndismayed by the vigor of the lusty young giant they were about to tame, so do we now face another era with vastly broadened horizons and with infinitely etter tools.

Our new Measurements Laboratory, completely quipped with the most modern facilities for the evelopment of new products, and of related materials nd processes, is an important milestone in our progess, a monument to those whose creative ability earned leadership in our highly competitive field.

The new tools it brings to our hands, the increased specialization and co-ordination it makes possible among our technicians, the high caliber and enthusiasm of our engineering personnel, all of these factors point to a continuing and accelerated progress.

Wonderfully new sciences crowd our heels, some with the veil still separating them from our comprehension, and add their clamoring challenge to the insistent call of older ones for continuing improvement. All of them demand inventive genius and creative skill.

We face them confidently, humbly conscious of our rich heritage, yet equally determined to fulfill the destiny which once was our founding fathers' and now is ours: that all men may benefit from our contributions toward the achievement of a continuously better way of life far beyond the dreams and expectations of those who lit the torch. So do we dedicate ourselves.

> *"First walked the dreamer with eyes intent and dwelling on the clouds that passed aloft, but seeing not the wafted white of summer day nor the gray scud of presaged storm; instead—a banner, silver light, and on it words, 'it is thy lot to help thy fellow men to better things. This, then, doest thou.'*
>
> *"And, in his tracks walked hundreds more—but never didst advance before him, yet listened to hear of the things he told which were beyond their ken, till his keen mind enlightened them with the bright truths of the ever-unfolding universe. This, then, the scientist."*
>
> *Anonymous*

MODERN MEASUREMENTS LABORATORY

General Electric's new Measurements Laboratory provides facilities for applied research, development, and design under conditions promoting the integration of these specialized functions for progress and service in the measurements field

By I. F. KINNARD

Meter and Instrument Engineering Divisions, Apparatus Department
General Electric Company

SHORTLY after the turn of the century, a shift in emphasis from mere mechanization to the organization of human effort for joint achievement in accordance with the principles of mass production marked the beginning of what has been called the second industrial revolution.(1) The present era of technological progress is due to the integration of the activities of specialists. Accordingly, the new Measurements Laboratory of General Electric's Meter and Instrument Divisions at West Lynn was conceived and built with a dual objective: first, to provide optimum facilities for specialists; and, second, to remove all physical barriers from the co-ordination and integration of their endeavors.

In order to appraise this new building designed to serve the measurements industry, it is appropriate first to examine the scope of measurements engineering and the type of organization required. With this scope defined and the characteristics of the organization established, the plan of the building emerges as a logical consequence.

Scope of Measurements Engineering

The objective of the measurements engineer is to anticipate and to meet the needs of science and industry in terms of the ever-growing variety of quantities requiring measurement and in terms of the great range of conditions and specifications applying to particular measurements.

Electrical measurement and control initiation is becoming essential to more and more industries. The fields of aviation, nucleonics, chemical processing, and medical research are among many providing constant challenge and opportunity. Electricity has played and is playing the central rôle in increasing man's ability to measure, to understand, and to initiate control of both electrical and nonelectrical quantities. Diverse nonelectrical variables such as position, temperature, pressure, and flow are converted into proportional electrical quantities which can be measured and indicated by established and uniform techniques.

As the scope of the measurements industry is broadened by the coverage of more kinds of variables, it is increased in depth by tailoring the measurement to fit the particular requirements of each job. The philosophy inherent in the development of a multiplicity of devices to measure each physical quantity was expressed 2000 years before there was created a technology capable of realizing it. Aristotle said: ". . . look for precision in each class of things just so far as the nature of the subject admits."(2) In modern times the quest for precision, appropriate operationally and economically to the object in view, has resulted in lines of instruments and measurement systems ranging from highly refined and almost incredibly accurate standards to simple indicators and devices giving approximate results.

The measurements industry is constantly developing new products for new applications and improving older lines with new materials and new techniques resulting in greater accuracy, lower cost to the user, and improved dependability. This work requires an organization embodying a high order of ingenuity, analytical ability, and inventive skill coupled with sound judgment and appreciation of the needs of the ultimate user.

Organization for Progress in Measurements

The steps involved in designing a new or improved measurements device, and the essential components of

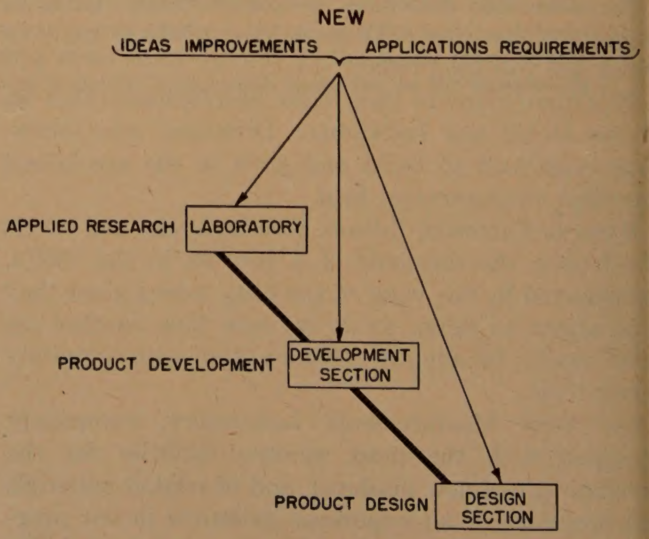

Fig. 1. Functions of a product-line technical organization

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(1)"The New Society," by Peter F. Drucker, *Harper's Magazine*, Sept. 1949.
(2)Aristole: *Ethica Nicomachea*, I, 3.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

an organization to carry out this work, may be visualized with the aid of the diagram in FIG. 1. Three separate and distinct functions are recognized: applied research, product development, and product design. Each of these functions demands such special capabilities that they are seldom combined in one individual or group. It is usual, in keeping with the complexity of modern industry, to assign responsibility for each function to a separate group of specialists. As illustrated, a new idea may originate with, or be introduced to the organization by, any of these functional groups. Its progress thereafter is a joint effort involving also the co-operation of the manufacturing organization and the sales organization.

LABORATORY

A sound basis for growth in, and contributions to, the field of measurements is provided by constantly applied research in new materials and processes and by continuous development of new measurement techniques embodying the fruits of that research. The metallurgists, chemists, physicists, and engineers of the laboratory organization—free from daily production problems—devote their major efforts to this pioneering work. These new measurement techniques must be checked continually and compared with established standards of measurement. When the laboratory has demonstrated the practicality of a new material, process, or measurement technique, the result is usually turned over to one of the development engineering groups for evaluation and application to a specific product.

DEVELOPMENT SECTION

The successful prosecution of a development frequently involves inventive solutions to problems and close co-operation with the laboratory in the application of new materials and processes. The development engineer must continually check, with the design and sales engineers, the course of the development against specifications and users' requirements.

The final product of a development section is one or more working samples covered by simple drawings and accompanied by evidence of ability to meet all foreseeable requirements of the intended application.

DESIGN SECTION

When development is complete, the new instrument becomes the responsibility of a design section which prepares the design for manufacture in co-operation with the factory organization. Parts and whole assemblies may be changed to provide for economical repetitive manufacture and the finished design is covered by detailed manufacturing drawings. The design section assumes full responsibility for the performance of the instrument in the field. To assist in maintaining the requisite high quality, the laboratory—as a disinterested party—is called in to act the part of a highly critical user, making constant checks on the finished product (FIG. 2).

Both the development and design sections look to the sales organization for information on the acceptance of a device in the field as well as on the future measurement needs of industry. The determination of what developments shall be undertaken and the formulation of design specifications for new products are influenced by the recommendations of the sales engineers based on market surveys and an intimate knowledge of customer requirements.

All of these activities must be guided by a management which has clear chains of command along functional lines as well as through the major product divisions. The technical organization must be closely knit, flexible, and quick to get results. Duplication of effort must be avoided and free interchange of ideas and information encouraged.

Fig. 2. New measurement techniques must be checked continually with established standards

HOUSING THE ORGANIZATION

The new Measurements Laboratory has been designed to fit the type of organization described and to implement the measurement-engineering objectives that have been outlined.

GENERAL DESCRIPTION

Architecturally, the sweep of the building's modern horizontal lines and extensive glass areas express the forward-looking spirit of the measurements industry while the warmth of the brick walls and simple disposition of the structure's mass keep it in harmony with the adjacent factory buildings and the traditions of a plant antedating the formation of the General Electric Company.

In plan, the five-story building resembles a letter "H" with elongated cross bar. It is steel-framed, with

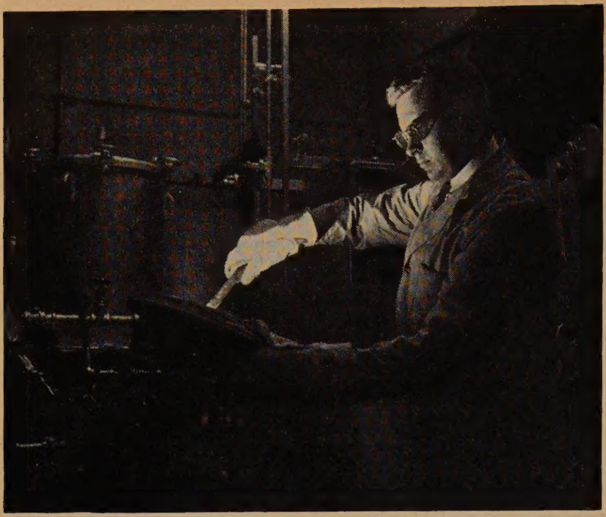

Fig. 3. Applied research in new materials provides a sound basis for growth

brick walls supported at each floor by steel spandrels. The horizontal bands of window sash almost encircling the building at each floor level are relieved by a tower at the intersection of the north and center wings, as shown in the front-cover illustration. At the base of this tower is the main entrance, with cut-glass mural designs symbolizing the standards of length, mass, time, and temperature to which measurements are referred.

The net usable floor area is approximately 100,000 sq. ft. Nearly half of this area is devoted to the laboratory proper and the remainder to the engineering, sales, and management offices, which are all included in the same building in the interests of convenience and efficiency.

ARRANGEMENT AND ASSIGNMENT OF SPACE

Early in the planning it was determined that it would be economical to distribute the necessary laboratory services vertically and through half of the building, with minimum horizontal runs. This consideration determined a vertical division of the building, the laboratory proper occupying one end (the south wing and half of the central portion, on the right of an observer facing the building) and the offices the other end.

The assignment of floors in the laboratory was made primarily on the basis of convenience. The Primary Standards and General Service Section was a logical choice for the first floor because of its many contacts with the factory, in calibrating all standards and test devices. On the second floor are located the materials and process experts, who are called upon to consult with both engineering and manufacturing personnel. Also on this floor are the laboratory stock room, machine shop, and similar service facilities. The services that require special provisions, such as isolation, high headroom, or special hood ventilation, are located in the basement or on the fifth floor (Fig. 3).

The third floor of the laboratory wing, together with adjacent areas on the second and fourth floors, forms the headquarters for the development of new devices. It has been found by experience that product development engineers can work best in a laboratory atmosphere, with ready access to laboratory equipment and personnel (Figs. 4 and 5). The experimental test laboratories are located on the fourth floor, convenient to the development sections.

Transformer development and experimental tests are located on the fifth floor because of their need for high headroom and accessibility to the roof for outdoor life tests. Experimental life tests are located here for the same reason.

Throughout the building, the partitions dividing the basic floor area into offices and laboratory subdivisions are of the movable steel type in order that area rearrangements can be made with minimum time and expense. A four-foot module is used, with provision for splitting it where necessary.

In the office half of the building, the engineering divisions are located on the lower floors for greater accessibility to the factory. Sales and general management are on the higher floors.

GENERAL FACILITIES

Easy access to all parts of the building is provided by three passenger elevators, a freight elevator, three full stairways, and wide central hallways (Fig. 6). A dumbwaiter connects the blueprint and photographic facilities in the basement with all floors.

The office portion of the building is illuminated by rows of fluorescent fixtures set flush into the sound-absorbing suspended ceiling. Convenience outlets are provided at intervals along corridors and outside walls. Additional outlets and connection boxes for telephones are distributed by means of cells in the floor.

Fig. 4. Development engineering sections work best in a laboratory atmosphere

The offices are characterized by a feeling of spaciousness. The low noise level and cool color-scheme contribute to efficiency.

In the laboratory wing the electrical and mechanical services common to most groups have been made available to all areas in order to assure flexibility. These services are run overhead in the corridors for maximum accessibility. The common electrical services are 120/-208 volts, 60 cycles; 240 volts, 60 cycles, 3-phase; and 120 volts d-c. An elaborate tie-line system provides for the temporary connection of special power supplies or telemetering circuits. The mechanical services include dry hydrogen, oxygen, nitrogen, city gas, compressed air, vacuum, hot water, cold water, and process steam.

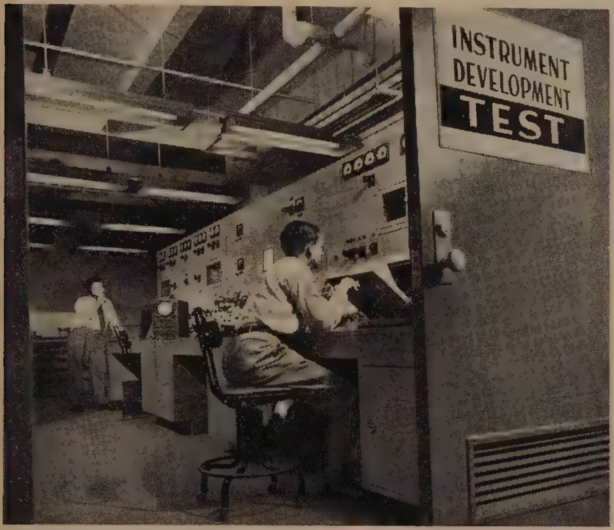

Fig. 5. Electricity is playing the central rôle in increasing man's ability to measure

To provide for growth and changing requirements, the electric power is distributed in bus-ducts which may be tapped at one-foot intervals, and the pipe lines are provided with T-joints at ten-foot intervals. These features, and the removable partitions, make rearrangement of the laboratory relatively simple.

The laboratory ventilation system provides six changes of fresh, filtered air per hour. All laboratory exhaust systems include back-draft dampers to prevent reverse flow into other exhaust systems which are not in use. A special water-flushed stack is available in the chemical laboratory to provide for the use of perchloric acid.

The entire building is heated by steam from the main-plant boiler room, controlled by a four-zone modulated system that anticipates changes in indoor temperature due to sudden changes in outside temperature.

To determine the performance of products under widely varying conditions, environmental test chambers each approximately ten feet square have been installed on the fourth floor. Five of these rooms hold constant temperature at 75 C, 50 C, 25 C, −20 C, and −40 C, respectively. A sixth is adjustable from −10 C to +40 C. In addition, there is an adjustable-humidity chamber and a constant-temperature chemical storage room. For noise determinations there is a test room in the basement effectively isolated from external sound and vibration.

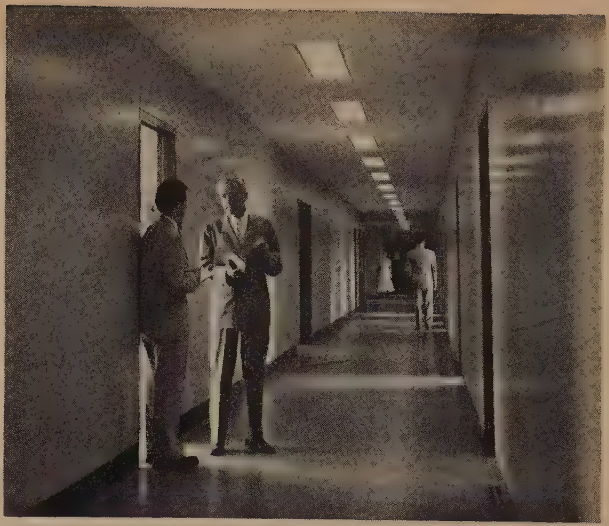

Fig. 6. The free interchange of ideas and information is encouraged

Both wings of the building are provided with storage facilities and generously equipped with conference rooms. In the north wing, convenient to the main entrance, is an auditorium seating 500 people, designed for engineering and sales organization meetings and also technical society meetings. The rear portion of this room may be set off by a motorized folding panel, segregating an area ideal for meetings of 50 people or fewer.

SUMMARY

The primary purpose of the Measurements Laboratory building is the housing of specialists in the technical fields of applied research, development, and design engineering. It is designed to facilitate the administrative organization of these specialists by product lines as well as their basic organization by function. To further this dual objective, contiguous office space has been provided for Management and Sales.

Offices and laboratory areas appropriate to the responsibilities and specializations of these groups, and flexible enough to meet their changing requirements, have been provided. The interchange of technical information has been made easy and natural by the juxtaposition of technical groups having similar problems but working on different product lines. At the same time direct natural communication exists within any given product organization, between the several specialized functional sections.

The best that architect, contractor, and equipment supplier can provide has been assembled to help forward the joint endeavor of broadening measurements horizons. The erection of this modern Measurements Laboratory is evidence of General Electric's faith in the future of industry and in the growth of measurements by electrical means.

STEELAB Polishing Bench, Series 5330. Just one of 413 items of laboratory equipment installed in this new building by Laboratory Furniture Co., Inc.

We are proud
to have had the privilege
of producing and installing
laboratory equipment in the new
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of GENERAL ELECTRIC

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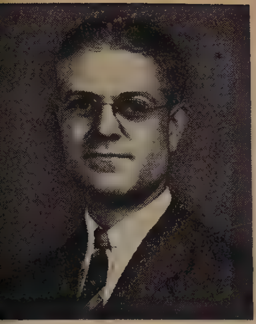


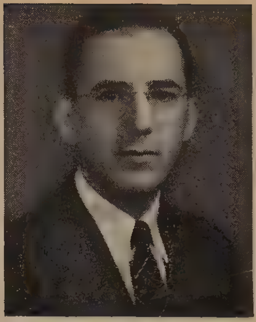
A. Brownell

FOR MEASURING FLUORESCENT LAMP STARTER TRANSIENTS

Reasons for the need of a special instrument for the purpose. Based on use of a standard neon glow lamp as indicator, the instrument is simple and measures the energy transient provided by the lamp starter

By A. BROWNELL and D. D. HINMAN

Lamp Development Laboratory, Lamp Department
General Electric Co., Nela Park, Cleveland, O.



D.D. Hinman

MOST of the fluorescent lamps in use today depend upon the operation of an automatic glow switch for starting. The glow starter (Fig. 1) consists of a two-electrode glow tube having one electrode made of bimetal in such a way that the heat produced during glowing will cause the bimetal to short-circuit the two electrodes. With the starter connected in parallel with the lamp the closing of the contacts places practically full line potential across the inductive ballast; and when the bimetal cools sufficiently to open the contacts, a high transient voltage appears across both the lamp and the starter. That transient is effective in starting the lamp.

A small capacitor (0.006 mfd) connected across the starter switch reduces arcing and loss of energy at the switch contacts; it tends to lower the maximum voltage of the transient but increases the time that the surge continues; it causes a slight welding of the contacts to provide a snap action, rather than a slow opening action; and in addition it suppresses most of the high-frequency oscillations which may be developed in the amp and which could cause radio interference.

The satisfactory performance of a starter requires that its characteristics be controlled within the following definite limits:

(1). The switch must start to glow and close at the minimum line voltage at which lamps are expected to start, and it must not glow at the maximum voltage across the lamp during operation. If the switch glows after the lamp is started, the contacts may reclose and extinguish the lamp.

(2). The contacts should close in as short a time as practicable to get fast lamp starting.

(3). If the contacts remain closed much less than one second, the lamp cathodes will not be adequately preheated, and closures of longer than about two seconds needlessly delay lamp starting.

(4). The transient voltage and energy must be sufficient to start the lamp.

All of these characteristics can be readily measured xcept that listed in Item (4). Attempts to measure the ransient voltage by means of a cathode-ray oscilloscope or a grid-controlled vacuum tube have always led to inconsistencies between the measured voltage and lamp-starting ability. Peaks of high voltage and short duration which are measured by these types of instruments are apparently ineffective in starting a lamp. Energy, as well as voltage, is necessary.

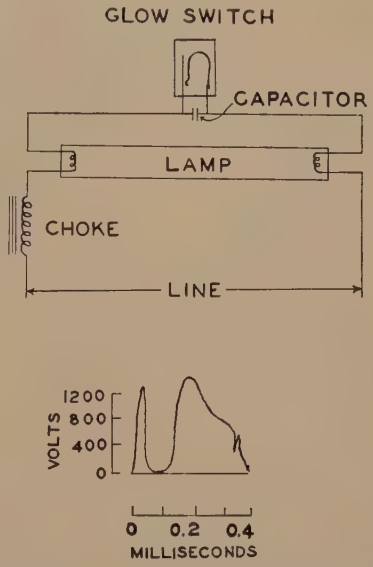


Fig. 1. Circuit diagram of ballast, lamp, and starter. Also, oscillogram of typical starter transient (as recorded by B. T. Barnes). The transients are variable with one or several peaks

Even though its ability to start a lamp is the ultimate test of whether a starter is good, an acceptance test based upon the starter's ability to start one lamp within ten seconds has often led to discrepancies. The transients produced by a starter on successive trials are quite variable, and the magnitude of the transient required to start a lamp is dependent not only upon lamp manufacturing variations but also on the lamp's past use and on the ambient conditions. Such factors as the length of time the lamp has been operated, the time since its last operation, the temperature, the relative humidity, and the presence of conducting material near the lamp can influence the ease with which the lamp starts.

For testing a new starter design and for occasional testing of starter quality, the starting of a large group of representative lamps yields dependable statistical

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data; but this method is far too slow for 100 percent testing of factory production. The usual procedure has been to use a small group of lamps and to require each starter to start one lamp. Lamps which are repeatedly started tend to attain the minimum starting difficulty characteristic of their design, but the lamps which are used for testing starters should have the maximum starting requirements encountered in normal lamps. Actually the results of using this method have not been as troublesome as might be supposed because most starters have produced a sufficient transient to start all lamps for which they were designed, and hence the test referred to has eliminated the defective starters which would not start any lamp.

When krypton replaced argon as a filling gas for certain sizes of fluorescent lamps, the starter testing problem became more serious. Krypton-filled lamps are harder to start than similar lamps filled with argon, and starters designed for argon lamps were in some cases marginal in starting the krypton lamps. The range of transients produced by the starters overlapped the range of transients required for starting. Some means of measuring the starter transient was needed; a means that would provide a measurement that would correlate with lamp-starting ability and permit the independent determination of starter variation and lamp variation.

A standard neon glow lamp has starting characteristics sufficiently similar to those of a fluorescent lamp to be useful for measuring starter transients. The circuit designed for making the needed measurements is shown in Fig. 2. An adjustable-voltage divider applies a portion of the transient voltage to the glow lamp, and the control dial is calibrated to indicate the transient voltage when the divider is so set that the glow lamp just flashes. Consistent results have been obtained by using the peak value of a 60-cycle voltage for calibration. A resistance of 0.1 to 1.0 megohm in parallel with the starter is satisfactory. Higher values make the flash of the glow lamp too weak to be observed and lower values decrease the measured value of the transient because of the energy lost in the resistance.

Individual NE-51 glow lamps were selected for equal "breakdown" voltages for the two electrodes, and the lamps were mounted within a grounded shield. Any other small glow lamp might be satisfactory. A small capacitor may be used for grounding, if the transient tester is used on an ungrounded power supply.

Glow lamps often have a higher breakdown voltage in total darkness than in the light, but a low level of room illumination is usually sufficient to eliminate this trouble. Since the instrument is calibrated in terms of peak volts, it is convenient to use the same units to express its measurements. The fact that the tester often indicates lower voltage values than an oscilloscope implies that it is not measuring strictly peak voltage. The good correlation between lamp starting and the transient-tester readings justifies its use. The tester may be used either to determine the maximum voltage produced by a starter by increasing the setting on successive contact breaks or to select starters whic exceed some predetermined value of voltage.

The first use to which this instrument was put wa that of calibrating a series of starters to produc transients of known value over a wide range of voltages With the calibrated starters it was possible to determine the required minimum starter transient for large selection of lamps representing different manufacturing lots under various conditions of use.

Figs. 3 and 4 show typical distribution curves fo several sizes of lamps and starters. The difference between krypton and argon in lamp-starting characteristics is shown in Fig. 3. A 350-volt transient will star 99 percent of the 100-watt argon lamps, but only 2 percent of the 85-watt krypton lamps. The influenc of a metal fixture is much greater for krypton-fille than for argon-filled lamps. Nearly all fluorescent lam installations utilize metal fixtures, but at high relativ humidity the effects of the fixture is reduced.

Both the lamps and starters have a broad distribution in values of the transient produced by the starter and of the transient required for lamp starting. I

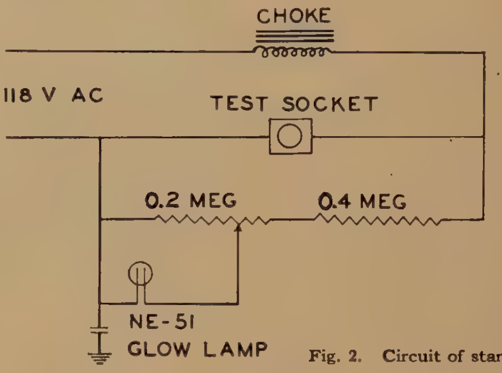

Fig. 2. Circuit of starter-transient test

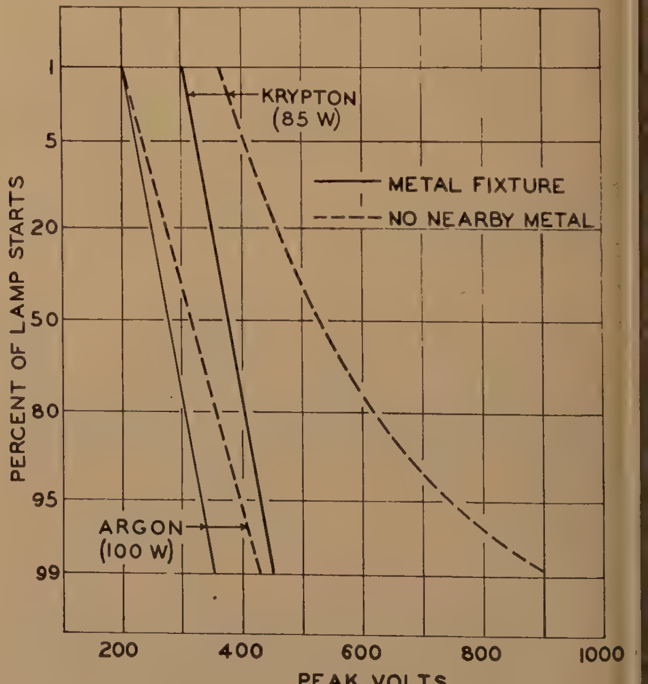

Fig. 3. The percent of 60-in. T17 (85-watt and 100-watt) lamps starting at various values of starter transient, as measured with the starter-transient tester

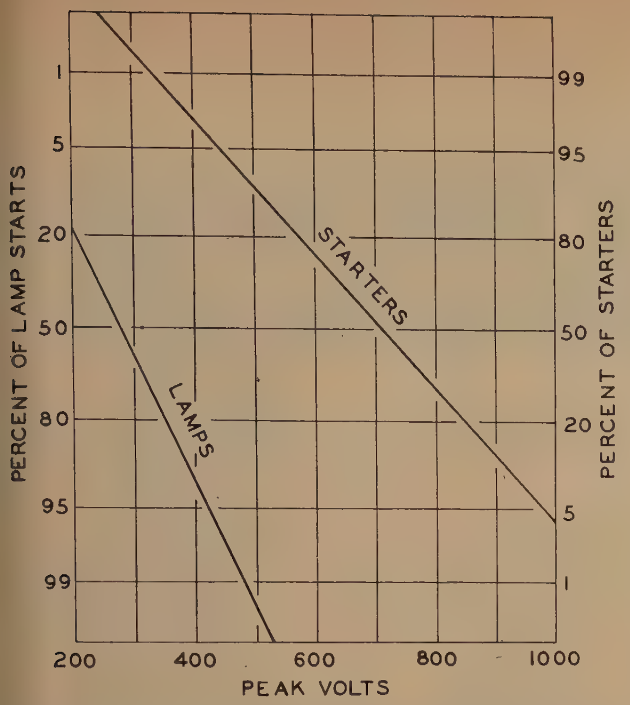

Fig. 4. The percent of 40-watt lamps starting at various values of starter transient, and the percent of starters producing transients of various values

esigning and testing starters, consideration must be iven to the probability of encountering unfavorable ombinations. After these preliminary data were ob-ained, the starter-transient tester was transferred to e factory for the production testing of starters. At resent, the visual attention of an operator is needed o select or reject each starter; but the tester can be odified for automatic operation. For the first time is practicable to set up inspection limits for starter ansients that assure an adequate margin of safety o cover the variations in lamp requirements.

The starter-transient tester is not a precision instru-ent; in fact, the exact physical characteristics of the ansient which are measured have not been deter-ined, but the tester does provide a simple means of easuring the ability of starters to start fluorescent mps, and it is performing that useful function. The uthors wish to acknowledge the suggestions of T. E. oulke which led to this instruments development.

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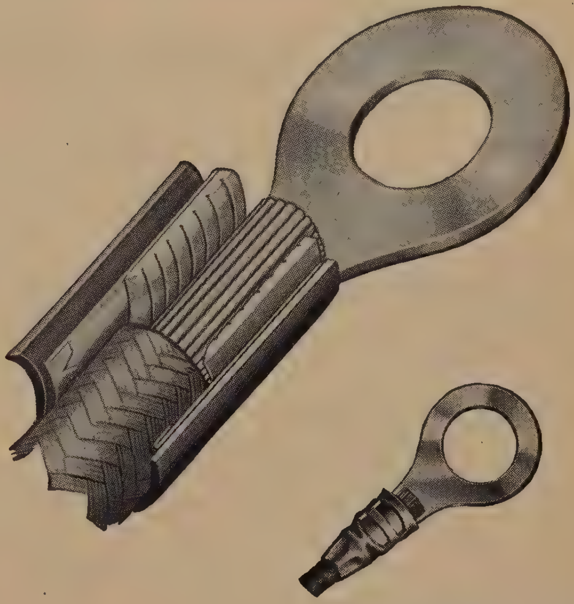

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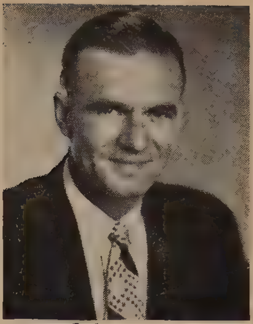
CONTROLLING HARDNESS AND MICROSTRUCTURE DURING INDUCTION HARDENING

uccess of certain applications dependent on thorough consideration of the asic factors and a better understanding of case-hardening fundamentals

By G. A. WARWICK
Fort Wayne Works Laboratory, General Electric Company



GAWarwick

DURING recent years induction heating has been given primary consideration when localized ardening of abrasion-resistant wear surfaces is speci- ed. This choice is often tempered by the lack of ade- uate control of certain variables which are inherent hen heating by induced currents. An example would be relatively thin-walled hollow piston pin which is de- gned for full-hardness penetration to a depth of 0.010 n. surrounding a tough ductile core over the remaining ross section. In another instance, it may be required o case-harden a small-diameter narrow-pitch geared haft for aircraft control motors.

IME-CYCLE DEFICIENCIES

In either of the examples mentioned, consistent re- ults on a high-production basis will usually prove ifficult because of the tendency toward overheating nd subsequent through-hardening of the entire cross ection when lengthy heating cycles are applied. A aphazard reduction in the time of power application ould prove just as troublesome since the required urface hardness may not be obtained without suffi- ient heat energy to fully austenitize the area to be ardened.

When very shallow case depths are necessary, the acuum-tube oscillator type of induction heating equip- ment is used. These machines are equipped with an nterval timer to control the duration of power applied o the heating coil. Experience has shown that uniform epth of hardness penetration by this means will de- end upon machine operation and line voltage, both f which may be subject to certain variations often reventing achievement of the desired results.

VALUATING BY TEMPERATURE

To overcome this deficiency a semiautomatic fixture, hown in FIG. 1, was designed and built to evaluate the erit of a method by which temperature rather than me would be the criterion for duration of the heating ycle. This device consists of a heating coil; live and ead centers for rotating test samples during heating; olenoid control for lowering the heated surface into an l or a water-spray quench; and a photoelectric cell nd relay system for controlling the work temperature.

In operation, a sample is manually located between centers with the gear and coil concentric. The photoelectric cell with appropriate filters and condensing lens to utilize infrared radiation is so focused on the work that, when the correct hardening temperature is reached, thermal radiation energizes the photoelectric cell and removes power from the heating coil. Simultaneously, the solenoid is energized and trips a trigger which brings the heated surface in contact with the quench.

This apparatus was used with a 50-kw electronic-type induction heater to harden a series of ¾-in. round test bars made from cold-drawn and annealed AISI C-1151 steel. This steel is a medium-carbon, resulphurized material particularly suited to localized mass-production hardening. The bars were heated in a single-turn coil with output transformer to surface temperatures of 800, 825, 850, and 875 deg C, respectively, in six power increments ranging from minimum to maximum heater

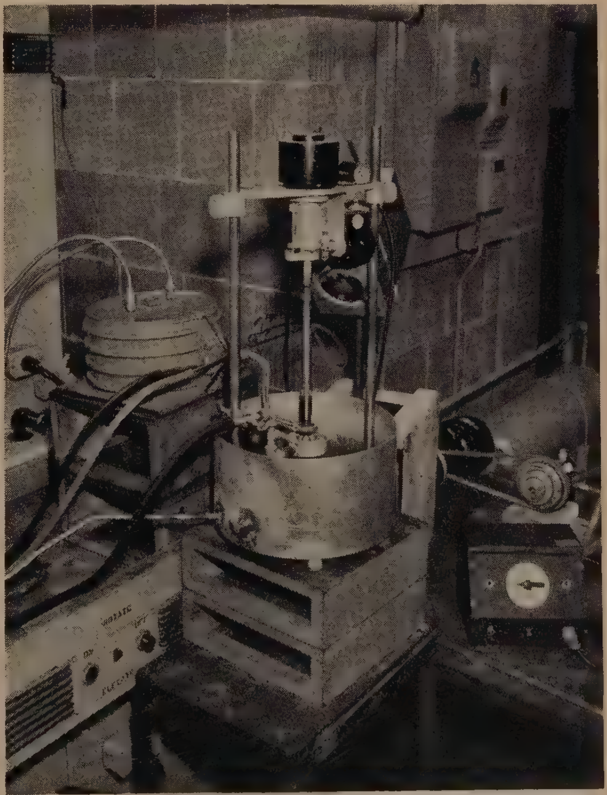


Fig. 1. Hardening fixture with photoelectric controller

This article is so paged that, without mutilating other articles, it can be adily removed for filing as a group of full-size consecutive pages.—EDITOR capacity, and water-spray-quenched under a line pressure of 40 lb.

Calibration of the photoelectric controller in temperature units was accomplished by means of a carbon block fitted in a tube-resistance furnace. The photocell was focused on one face of the block and a potentiometer thermocouple imbedded in the opposite face. The block was heated in 50 deg C increments and the corresponding resistance values to open the photocell relay circuit were located on the adjustable resistance dial.

Following heat treatment, each bar was checked for surface hardness, then was sectioned longitudinally, and further prepared for microscopic examination. Data obtained from these metallographic samples include accurate measurement of the effective and total case, and a microhardness traverse of the hardened area. Curves, as in FIG. 2, were prepared from these data to study the material characteristics for wear-resistant applications such as the examples cited earlier. An attempt was made to evaluate induction-hardening properties in terms of some fundamental relationships which determine hardness distribution and structural composition. This prompted a search for some method by which the temperature gradient during hardening could be used to predict and control the case composition within the narrow limits required.

PREDICTING AND CONTROLLING CASE COMPOSITION

The effect of surface austenitizing temperature and power density* on the hardness distribution is shown in FIG. 3. As is expected, the total case consists of two parts: first, a zone of high uniform hardness containin
nearly 100 percent martensite beneath which is, sec
ondly, the transition zone of intermediate hardnes
composed of a mixed structure of martensite and pro
eutectoid ferrite. Momentarily disregarding the fac
that the heat energy is induced in a thin layer beneat
the surface, the depth of each hardness zone depend
upon conductive heat transfer. This is a function of th
surface temperature which determines the gradient t
produce heat flow, and the power density which estab
lishes the heating rate and limits the time available fo
induced heat to flow inward prior to the quench.

The martensite-zone depth is directly related to th
surface temperature and inversely related to powe
density. This also is true of the transition-zone dept
although conditions there are somewhat more comple
because of the cooling effect of the core material, de
fined as that portion of the bar cross section which
not heated above the lower critical temperature. Fo
the present consideration the martensite zone shoul
be regarded as the effective case depth, although unde
certain circumstances some arbitrary point may be ac
ceptable within the transition zone where 50 percen
of the structure consists of martensite.

Additional data are plotted in FIG. 3 to aid th
interpretation of the hardness distribution curves. Th
graph shows the actual depths of the effective case an
transition zone compared to the total case depth;
confirms the hardness distribution by emphasizing th
relationships just described.

An interesting point is revealed by FIG. 4 where th
same data are reproduced on a percentage basis. Eac
point on the temperature axis represents the average

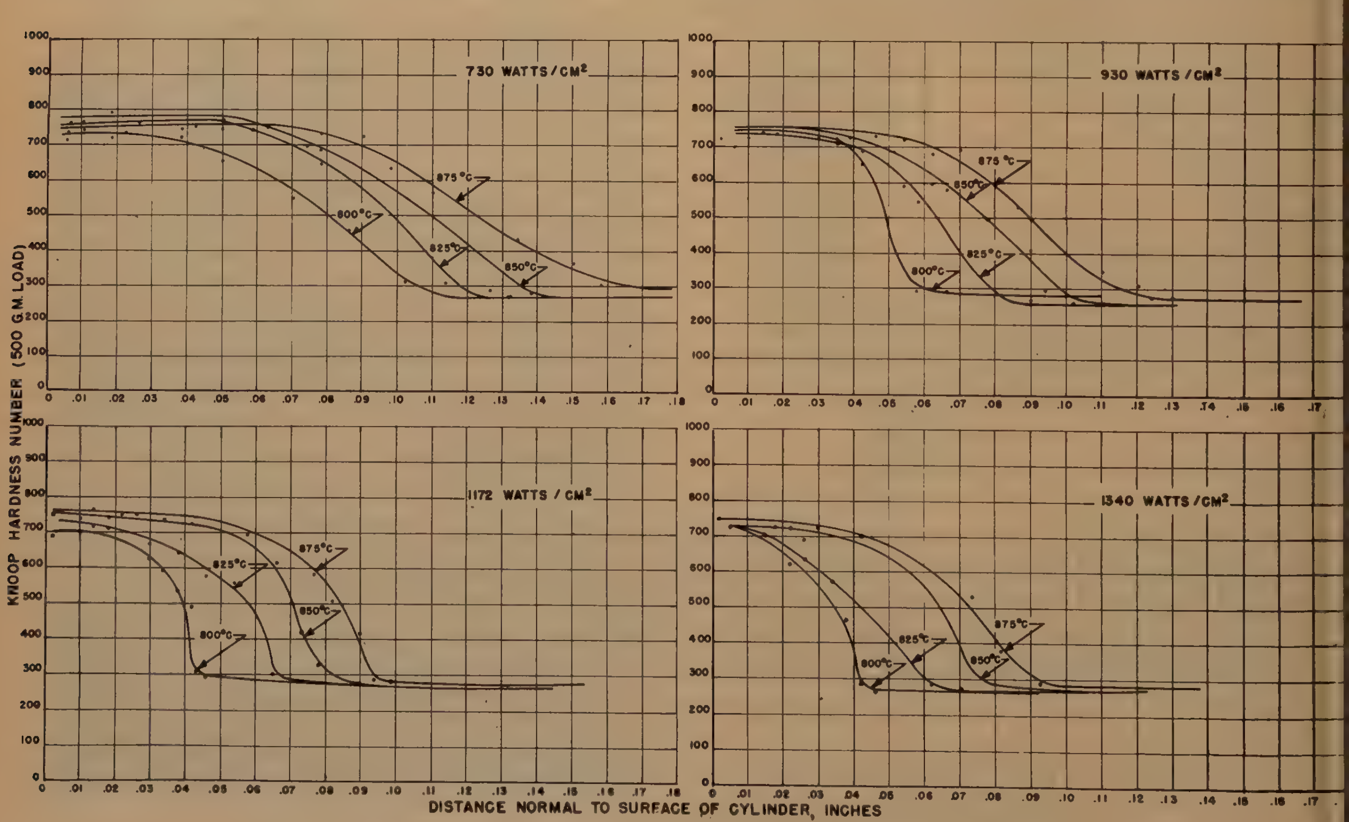


Fig. 2. Effect of surface temperature on hardness penetration at different power densities

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* Kilowatts per sq cm of surface area exposed to high-frequency flux.

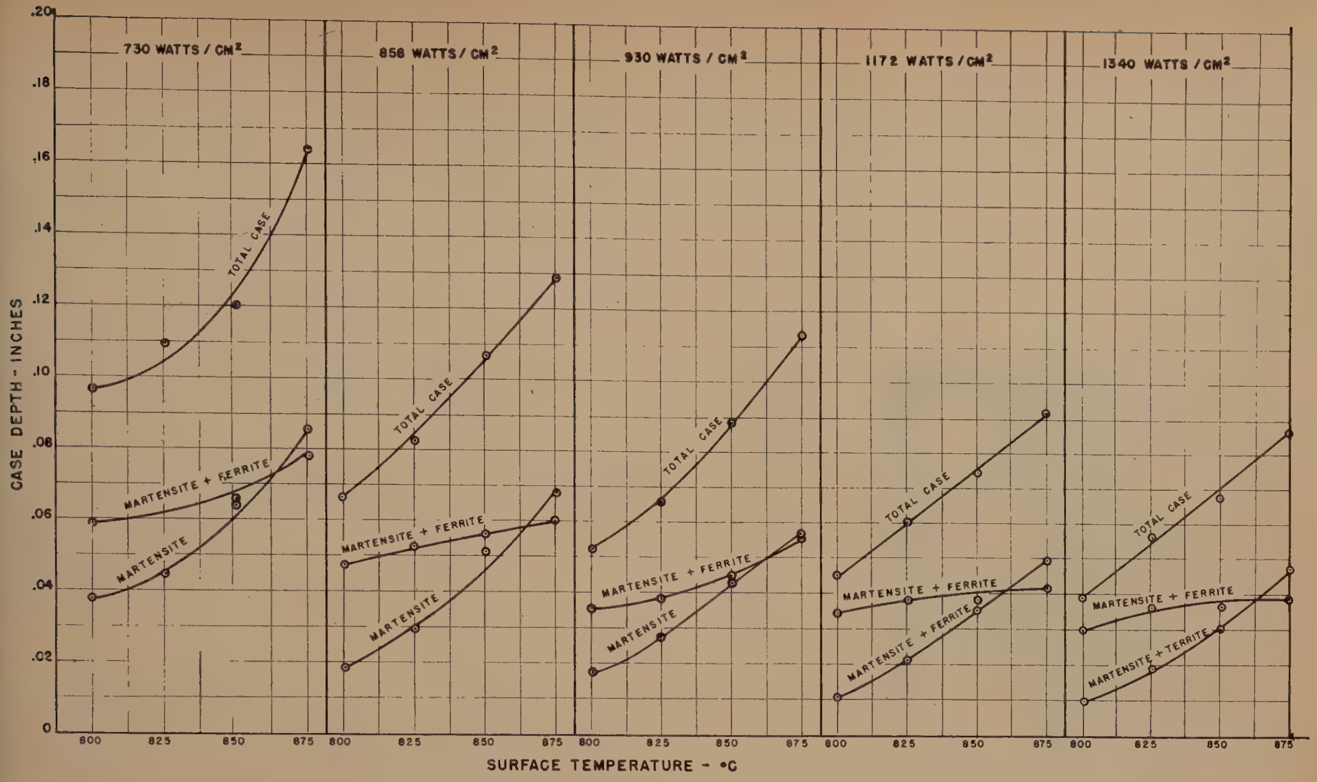

Fig. 3. Case depth vs surface temperature at different power densities

six separate samples, each heated by a different power density. The percentage variation of the case composition at any temperature varied so slightly that the arithmetic average is valid. This would indicate that power density is relatively unimportant when the case-hardened area is judged on percentage composition. As the surface temperature is increased, the percentage of total martensite will increase at the expense of the intermediate products regardless of power density.

EFFECT OF FREQUENCY ON CASE DEPTH

So far the effect of frequency has apparently been disregarded as a factor affecting the case depth. When steel is heated inductively, complicating conditions are introduced because of the changing magnetic intensity and permeability as the temperature increases. Since frequency establishes a "skin effect," permeability will determine theoretically the depth of current penetration while the metal is still below the Curie temperature. Moreover, when the permeability becomes unity at the Curie temperature, steel should behave as a nonmagnetic material and the current penetration is essentially constant. From a practical standpoint this conception of pure induced current heating is usually believed to be of minor importance to the depth of hardness penetration. With any finite heating time, and during the interval between heating and quenching, conductive heat transfer occurs to the metal below the current-carrying layer. Usually, this heat conduction limits the minimum case depth.

Pure induced current heating is most nearly approached in instances where very high power densities and minimum austenitizing temperatures can be used, and when recognition is given to the fact that any increase in temperature or decrease in power will afford an opportunity for heat conduction within the metal. As these variables change in the direction indicated, the over-all temperature tends to equalize, bringing more metal above the upper critical temperature and less within the range between the upper and lower critical temperatures.

The foregoing statements regarding hardness and microstructural distribution are based on the assumption that the water-spray quench used for these tests is severe enough to fully harden any portion of the bar cross section that is heated above the upper critical by high-frequency current. Several quenching media and methods were tried before the water spray was chosen. Any immersion quench was unsatisfactory, even when the part is rotated after immersion and the quenching

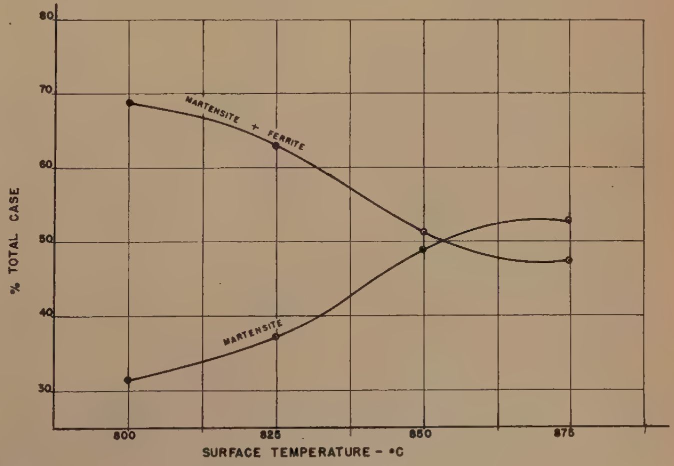

Fig. 4 Effect of surface temperature on case percentage composition

medium is agitated by a propeller stirring device. On the other hand, the water-spray quench is generally conceded to possess one of the highest heat-transfer coefficients so that hardenability would be limited only by inherent characteristics of the steel.

It has been shown thus far that conductive heat transfer is definitely responsible for a portion of the case-hardened area, although its effect cannot be established definitely because heat is also generated beneath the surface by induced currents. Moreover, the temperature of the heated area is not constant because of the exponential induced current distribution.

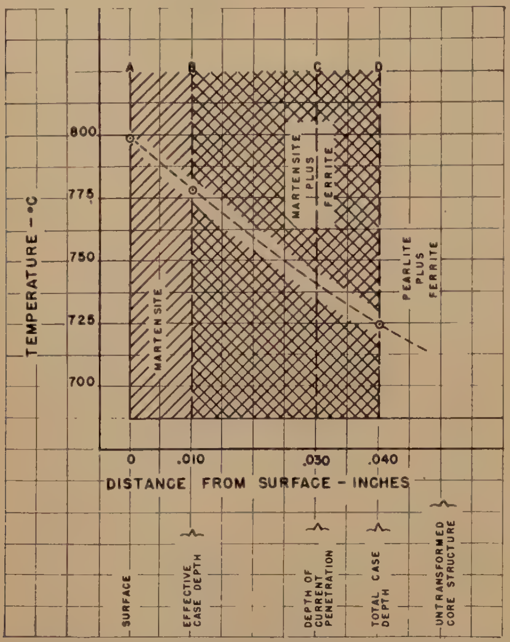

Fig. 5. Schematic diagram of temperature gradient necessary to obtain microstructure of sample heated to 800 deg C. Power density is 1340 watts/cm²

As an example, a test sample was heated to 800 C by the highest power density available. Microscopic examination of the resulting case reveals the product of the specific thermal history indicated in Fig. 5. This diagram represents a longitudinal section through the bar and shows the microstructural constituents and temperatures necessary to attain these conditions. According to the previous assumption that the water-spray quench is severe enough to completely harden all the volume induction-heated above the upper critical temperature (approximately 780 deg C), it can be said that this occurred to a depth of 0.010 in. (points *A* to *B*).

The structure further indicates that the area between *B* and *D* was heated between the upper and lower critical temperatures, because below the lower critical no structural transition takes place. Therefore, the total case depth determines the volume heated above the lower critical so that any untransformed components of the original annealed structure (pearlite plus ferrite) will be considered the relatively "cold" core. The area between points *A* and *C* shows that portion of the total case in which heat is generated by induced currents, while heat between *C* and *D* is the result of conduction. It is important to note that in this example of minimum austenitizing temperature and maximum power density, conductive heat transfer is of secondary importance.

It now remains to confirm these observations in terms of the electrical characteristics of the induction-heating apparatus and thermal properties of the test material. If all heat was transferred by conduction without internal induced currents, this problem would be simplified through the use of Russell's tables⁽¹⁾ or the Gurney-Lurie charts,⁽²⁾ both of which rigidly describe the temperature distribution of a part heated or cooled by conduction only.

THE HEAT-FLOW PROBLEM

A search of literature on induction-heating applications produced some formulas which seemed to offer a solution to the heat-flow problem. One of the first complications concerns a method for accurately measuring the power output of a vacuum-tube oscillator. The accepted procedure is by calorimetric methods which did not seem practical when an output transformer is used with the heating coil. A possible alternate method was found in the work of Stansel⁽³⁾ as an equation for the rate of heat development by eddy currents in a conducting mass which is exposed to a high-frequency flux. This equation states

$$P = \frac{2\pi\rho N^2 i^2}{l} \Delta F(r) \qquad (1)$$

where,

P = Power (watts)
ρ = Resistivity of charge (ohm–cm³)
N = Number of turns in coil around charge
i = Current in coil (amp)
l = Length of charge (cm)
Δ = Index ratio
$F(r)$ = Resistance function

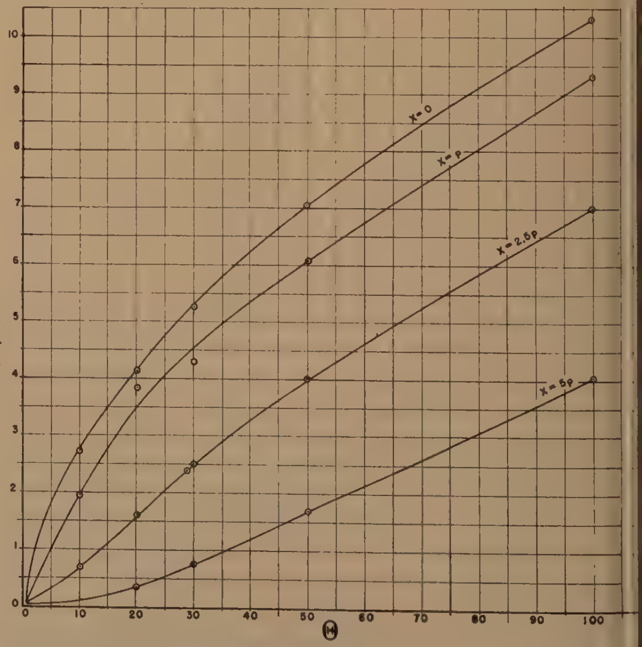

Fig. 6. Relation between θ and f(θ, X) in equations (4) and (5). (Data from Brown, Hoyler, and Bierwirth, p. 159)

When this test sample was heated to 800 deg C by the highest available power input, the transformer primary coil current was 300 amp. According to the relationship $I_1N_1 = i_2N_2$, (2)
and with a 6:1 turn ratio and an estimated efficiency of 80 percent, the current in the secondary single-turn heating coil would be

$$(300 \times 6) \times 0.8 = i_2 \times 1$$
$$i_2 = 1440 \text{ amp.}$$

The index ratio (Δ) is defined by Stansel as the parameter of an induction-heating circuit according to the shape of the charge. For a solid cylindrical part, this is the radius divided by the depth of current penetration. Assuming that above the Curie temperature, steel will be magnetically similar to a good conductor, such as copper, the equation

$$p = \frac{1}{2\pi\sqrt{10^{-9}\mu_r\sigma f}} \tag{3}$$

can be used, where

p = Depth of current penetration (cm)
μ_r = Relative permeability of charge
σ = Electrical conductivity of charge (mho-cm³)
f = Frequency (cycles/sec)

Using the most precise value available for conductivity at 800 deg C, the depth of current penetration is calculated as 0.075 cm so that Δ is 0.953 cm divided by 0.075 cm or 12.7. When the index ratio is known, the resistance function F(r) can be determined by complex mathematics solved in graphic form by Stansel. Referring to this work, the resistance function is approximately 0.68 when Δ is 12.7.

Inserting the known values in Equation (1), the power input to this sample is calculated to be 9850 watts. The surface area exposed to alternating magnetic flux is 7.36 sq cm so that the applied power density is 1340 watts per sq cm. It is now possible to use some equations developed by Brown, Hoyler, and Bierwirth[(4)] to calculate the temperature gradient within the induction-heated part. These investigators have solved the differential equation of heat flow where internal heat generation is included to obtain a relation for the temperature gradient between the surface and any point along the bar cross section. This is given by the equation

$$T_1 - T_2 = \frac{p\,P_T}{8.374\,k} f(\theta, X) \tag{4}$$

$$\theta = \frac{4\alpha^2 t}{p^2} \tag{5}$$

$T_1 - T_2$ = Temperature gradient (deg C)
p = Depth of current penetration (cm)
P_T = Power denisty at surface (watts/cm²)
k = Thermal conductivity of charge (c.g.s. units)
α^2 = Thermal diffusivity (cm/sec)
t = Heating time (seconds)

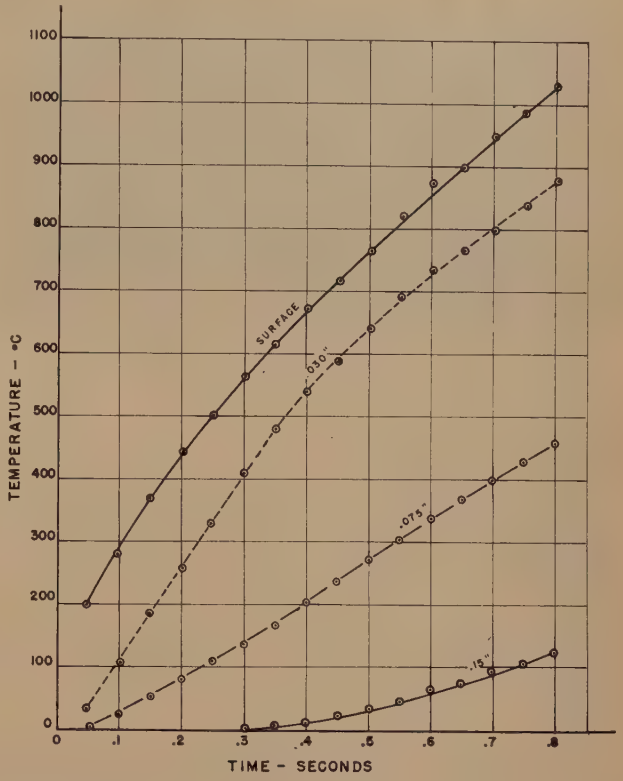

Fig. 7. Calculated thermal gradient of sample heated with power density of 1340 watts/cm²

FIG. 6, prepared from data given by these investigators, is used to determine $f(\theta, X)$ as a function of θ which is calculated from known data. This consideration of the test sample heated to a surface temperature of 800 deg C with 1340 watts/cm² power density shows that at some time interval during the heating cycle, say t=0.5 sec, the value $\theta = \frac{4 \times 0.0508 \times 0.5}{(0.075)^2} = 18.1$ where α^2 is the thermal diffusivity of C-1151 steel. When θ is 18.1, FIG. 6 shows that $f(\theta, X)$ is 3.90 at the surface (X=0), 3.30 at the maximum depth of current penetration (X=p), and 1.30 in the area heated only by conduction (X=2.5 p). These values can now be used in Equations (4) and (5) to calculate the temperature gradient within the test sample.

This procedure was used to prepare FIG. 7. By comparing these curves with FIG. 5, it is noted that some deviation exists between the calculated gradient and the thermal requirements for the measured microstructure of the hardened case. From a rigid mathematical standpoint, there is little doubt that Equations (4) and (5) describe the thermal gradient necessary to obtain the measured case composition. However, the lack of correlation between calculated and observed temperatures is not unusual in view of the somewhat uncertain methods and assumptions required to calculate power density and depth of current penetration, both of which can introduce considerable error in the final result.

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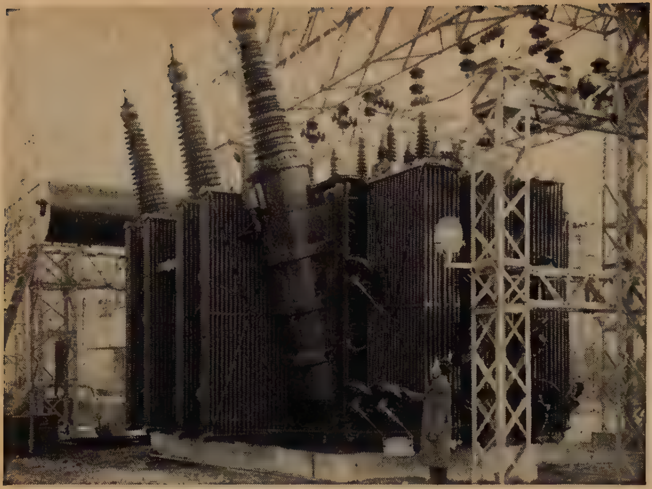

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CONTROLLING HARDNESS

(Continued from preceding pag

CONCLUSIONS

The foregoing analysis is presented to illustrate on approach toward a better understanding of some of th fundamentals concerned with case hardening by induce current heating. The future success of certain applications which previously have met with overwhelmin production problems will be enhanced if three basi factors are given more thorough consideration by thos whose duties involve the design and processing of induction hardened parts. These are:

(1). Relationship between induced energy and con ductive heat transfer in regulating case dept

(2). Methods for eliminating inconsistent temperature gradients during heating cycle

(3). Use of suitable fixtures and adequate contro measures to insure minimum time lapse between heating and quenching.

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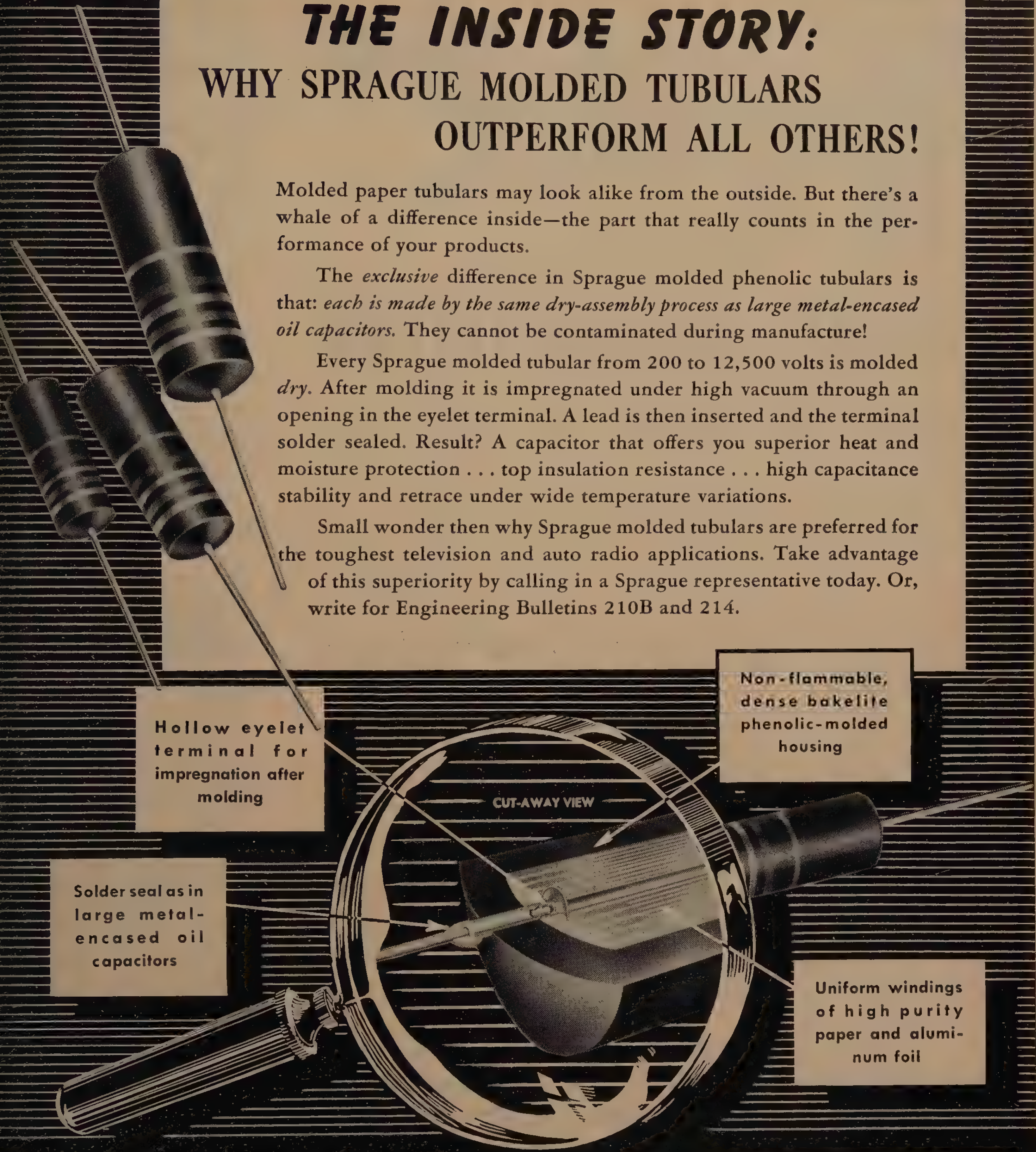
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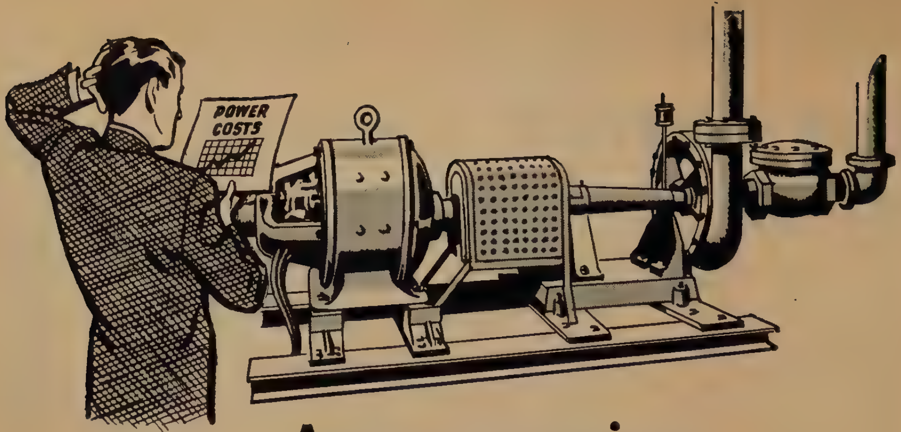

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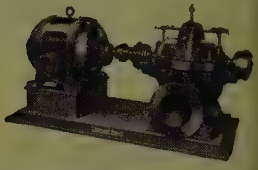

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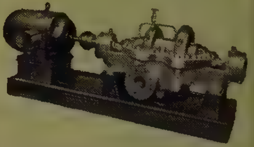

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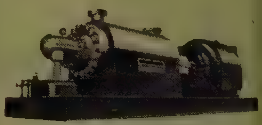

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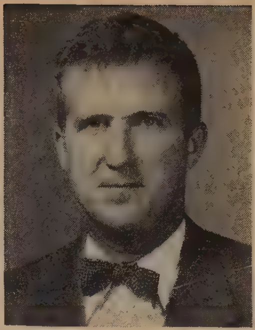
MEASURING AND EVALUATING NOISE

Problems encountered and difficulties to be overcome by sound engineers in attacking the disturbing and elusive factors peculiar to the phenomenon of noise, its measurement, and evaluation



Augustus H. Fiske Jr.

By A. H. FISKE, JR.
Thomson Laboratory, General Electric Company

WE ALL know what noise is—or do we? The sound of a steam locomotive whistle may be music to the ears of a retired railroad man but only noise to his next-door neighbor.

This article presents the problems facing the engineer who not only must measure but also evaluate noise. Usually, when one considers a measurement problem, it is logical to start with a clear definition of what it is that one is going to measure. Having defined this, and knowing the approximate size and other characteristics of the phenomenon, one proceeds to select a unit of convenient size, then to describe a measuring device and how it is to be calibrated in terms of the defined unit. An outline of the techniques of using the instrument is then in order. Finally, one can conclude the article with a learned discourse on the expected accuracy of the measurements and sources of error. Unfortunately, the noise-measurement problem does not yield to such a simple attack.

DEFINING NOISE

Subjectively, noise might be defined as unwanted or disturbing sound. Thus, the tick of a fine watch is not noise but rather a pleasing sound which adds immeasurably to the esthetic and even monetary value of the watch. In fact, it would be quite annoying if it were not there. Likewise, a dead-quiet room cooler is not nearly so effective as one that emits a cool, soothing, zephyr-like sound. Does your front door close with that firm, reassuring click?

INSTRUMENTS FOR MEASURING NOISE

Up to the present time, no instrument has been invented which is capable of measuring noise subjectively. In fact, there is some doubt that such a device will ever be made; too many variables—both psychological and physical—are involved. However, considerable progress has been made in the development of objective measuring instruments. The most common of these is the sound-level meter, popularly and misleadingly known as the noise meter.⁽¹⁾

This is a compact, portable device, usually battery-operated, containing a microphone, electronic amplifier, and indicating meter. The sound arriving at the microphone is converted to an electrical signal which is amplified, rectified, and applied to the indicator. Special filters called weighting networks are included in the circuit. These circuits provide the instrument with frequency-response characteristics somewhat like those of the human ear, thus causing in an extremely crude way the meter reading to correspond more closely to what the human ear hears. The readings obtained with this instrument are related to the average sound energy. The instrument is calibrated to read in decibels; the higher the number of decibels, the louder the sound. Zero db represents a sound level close to the threshold of audibility, while in front of an automobile horn the level may be as high as 120 db. Ordinary conversation is carried on at a level of approximately 65 db. Thus the db reading is roughly a measure of how loud the sound is.⁽²⁾

Another useful device in the study and measurement of noise is a frequency analyzer which breaks down a complex noise signal into its various frequency components. There are many different kinds, the most common two being the heterodyne or constant-bandwidth type and the degenerative or constant-percentage-bandwidth type.⁽³⁾ Although both types have inherent advantages and disadvantages for all-round noise measurements, the degenerative analyzer is probably the best. It is lighter, simpler to use, has fewer adjustments, and is inherently more stable than the other. The frequency analyzer measures the average energy at various frequencies of the noise spectrum. Like the sound-level meter, it also is calibrated to read in decibels.

THE HIDDEN AND ELUSIVE

Until a few years ago these two basic instruments were the only ones available for making noise measurements. They were the only means for "putting a number" on the phenomenon. However, it has been found that the numbers obtained with these instruments provide no measure of the "quality" or "annoyance value" of noise. In fact, experience has shown that, except for giving valuable clues as to the source of a noise, such analyses can be downright misleading. For instance, the largest component in a frequency analysis may not be the most important from the

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(1) Numbered references are listed at the end of the article.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

listener's point of view. This is particularly true of transient noises characterized by thumps, bangs, and clicks.

The writer was once given the problem of reducing the noise in a hermetically sealed refrigeration compressor. Besides the general running noise of the machine, there was a sharp well-defined click which occurred once each revolution. This click, which sounded like a loose wrist pin or crank, was the outstanding characteristic of the noise and, besides being disturbing, suggested a mechanical defect due to poor workmanship. It was the wrong kind of noise to come from a quality machine. Also available was a similar compressor which was operating smoothly without the clicking sound. Frequency analyses of the noise from both machines were made. At first glance, both were identical. Closer scrutiny, however, disclosed a small frequency component at 2500 cps present in the analysis of the noisy unit but not in the other. The click turned out to be an unstable discharge valve which buzzed intermittently, like a saxophone reed, near the top of each compression stroke. Changing the valve eliminated the click, reduced the annoyance factor, and greatly improved the noise quality. The over-all decibel reading remained unchanged.

Thus, it is only natural to ask: What is wrong with our measurement technique? Is it that our present equipment needs more accurate calibration? Is the trouble in our microphones and amplifiers? Are they so full of distortion as to be inadequate to the task? The answer to all these questions is "No."

The fact is that noise is an extremely smart and sophisticated animal, which we are still trying to catch in an obviously old-fashioned trap. We must give up our blind faith in the simple cheese, snapping springs, and poison bait, and look for more adequate devices.

Optical Analogue

To see more clearly in what direction we should search, let us consider a parallel situation in the light-measurement field. Suppose a lighting engineer were given the problem of evaluating the famous "Mona Lisa" portrait. He is required to come up with a single number which he must obtain from available instruments. The simplest device for his measurements is a light meter. Consequently, he mounts the portrait on the wall and measures the reflected light. Immediately he is in trouble; for every position of his meter he gets a different reading. Then, to eliminate reflected light from other sources, he hangs black curtains on the wall and around the portrait, but in spite of all precautions he still obtains a different reading for every position of his light meter. Finally, in desperation, he takes the average of a large number of readings, and, with tongue in cheek, turns in his data. How like a sound engineer armed only with his noise meter! How foolish to assume that the aesthetic value of the portrait is a function only of how much light it reflects! How foolish to believe that noise quality or annoyance is a function of total energy alone!

Let us arm our lighting engineer with glass prisms lenses, and all the other necessary paraphernalia for color analyses, and send him back on the job. With much care he analyzes the reflected light from the portrait He determines exactly how much red, yellow, green blue, and all the other colors there are. His spectral analysis is complete. The data he obtains gives considerably more information about the painting than the light-meter reading alone gave us. At least we know what colors are present but we still cannot reconstruct the visual impression from these numbers There is nothing in these data to even suggest the famous smile. Likewise, a frequency analysis of noise tells us the general energy distribution but we still cannot reconstruct the original.

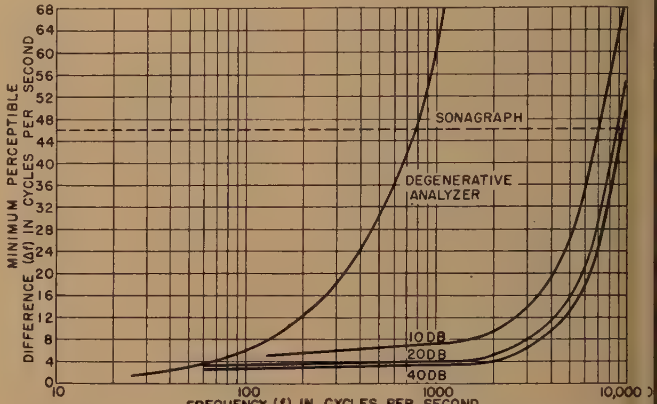

Fig. 1. Variation of frequency discrimination Δ_f with frequency for various sensation levels (From Olson "Elements of Acoustical Engineering" after Shower and Biddulph)

The skeptic at this point might be invited to consider what his favorite phonograph record would sound like played backwards. Yet forward or backwards, the classical frequency analysis of any passage would be exactly the same. Obviously, the time sequence o the musical notes is just as important as the notes themselves. What is not so obvious is this fact: It is the way some musicians are able to control the attack or build up on their musical tones that makes them worthy to be called artists who create music, and it is one of the most important skills that sets them apart from their less-gifted fellow travelers who make noise.

Mona Lisa Again

Let us return once more to the Mona Lisa portrait This could be uniquely defined by designating for each point on the canvas a color and an intensity Notice that the spatial co-ordinates for these points are equally as important as the color value themselves if not more so. After all, a black-and-white photograph is recognizable in spite of the fact that there are no colors displayed at all, just different shades of gray This technique of defining the portrait in terms of spatial co-ordinates is exactly what the printer uses every day in reproducing photographs. We are all acquainted with the multidot-like structure of the average news photo. The more dots per square inch, the more faithful the reproduction. The fineness of the grain required to bring out the innuendo in the Mona Lisa's smile can be found by trial, and is determined by the visual acuity of the human eye.

NEW NOISE-MEASURING DEVICE

Recently, a new type of measuring instrument called the Sonagraph(4) has become available to industry. This device is capable of drawing a noise picture known as a sonagram. It was originally developed for studying speech sounds, and needs considerable modifications to adapt it to industrial noise measurement. A trained observer can study a speech sonagram and determine from it not only the words spoken but also make a fairly good guess as to whether the speaker came from Brooklyn or Alabama. The sonagram produced by this device is a black-and-gray picture 4 by 11 in. The horizontal dimension is time and corresponds to approximately 2½ sec time going from left to right. The vertical dimension is frequency—low frequencies near the bottom, high frequencies near the top. The intensity of any frequency component in a noise is plotted in the picture as a dark mark located vertically by its frequency, and horizontally by the instant of time at which it occurs. Thus a steady tone at 1000 cps appears as a dark horizontal line across the picture about one inch from the bottom. An intermittent tone appears as a dashed line.

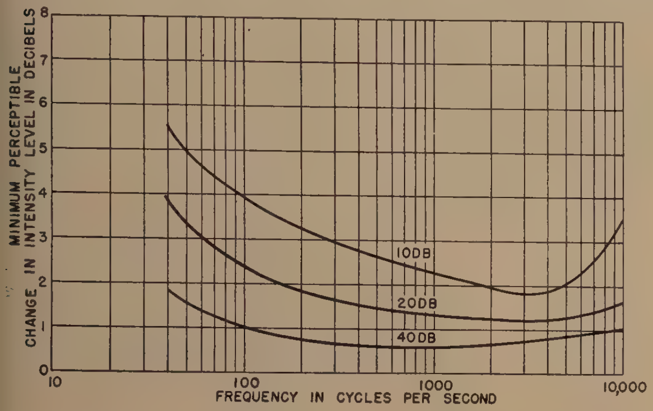

Fig. 2. Minimum perceptible change in intensity level of pure tones as a function of frequency for various sensation levels (After Fletcher "Speech and Hearing")

A picture of noise containing all frequencies varying in a random manner would appear as a dark gray smudge all over the field. A sonagram of an electric hand drill appears as a series of dark horizontal bands each one corresponding either to the meshing frequency of gear teeth, to electrical noise, or to the siren effect of the ventilating fan. A picture of the stopping transient is very useful in separating the electrical noise from the other components, for at the instant of switch opening, all the noises of electrical origin stop, while those due to the rotating parts droop downward as the speed decreases. The dynamic picture thus helps the sound engineer not only by giving him a new way of looking at noise, but also by separating to a certain extent the sources of noise.

NOISE-QUALITY STUDIES

To make this type of picture of maximum value for noise-quality studies, time- and frequency-discrimination characteristics similar to those of the human ear must be built in. For instance, laboratory tests show that time discrimination on the horizontal scale need not be better than about 10 milliseconds; that is, one should be able to measure the duration of a frequency component in the noise signal to the nearest 1/100 of a second. The frequency discrimination varies with frequency and is best defined by a study of the curves in FIG. 1. From low frequencies up to about 2000 cps one should be able to discriminate between frequencies about 5 cycles apart. Above this middle frequency the bandwidth should increase on approximately a constant percentage basis approaching 60 cycles at 10,000 cps.

Plotted on this same curve are the frequency characteristics of the present Sonagraph and of a well-known degenerative feed-back-type analyzer. It can be seen that the degenerative type approaches more closely to the desired characteristic.

FIG. 2 defines to a certain extent the dynamic depth required for the perfect sonagram.

REQUIREMENTS OF A NOISE ENGINEER

Until these new measuring instruments are developed to a practical stage the successful noise engineer must continue to be somewhat of a philosopher. He must not only possess a reasonably normal pair of ears but also plenty of good old-fashioned horse sense. These two are the most powerful tools he has to work with. He must also be flexible in his viewpoint and have a thorough and complete understanding of all the factors both physical and human which enter into each noise problem. He must never rely too heavily on meter readings, for his work is still an art and not a science.

REFERENCES

(1) *American Standards Association*, Bulletin Z-24.3, 1944.
(2) *ASA* Bulletin Z24.2, 1942.
(3) *Noise Primer* (2nd Edition), General Radio, 1946.
(4) *The Sonagraph*: Kay Electric Co., Pine Brook, N. J.

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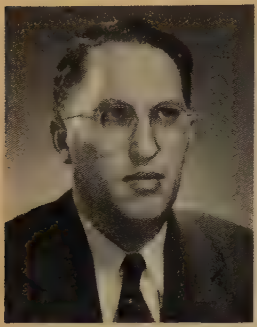
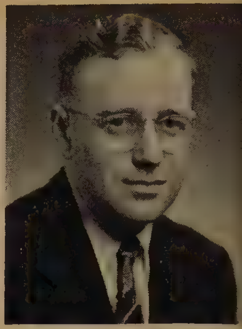


Lewis R. Runaldue

Newly developed means for improving transformer-testing facilities illustrates some basic concepts in obtaining continuously adjustable voltage and frequency with high accuracy over the desired range



Harold J. Parker

By L. R. RUNALDUE and H. F. PARKER
Transformer and Allied Products Laboratory
General Electric Company, Pittsfield, Mass.

TOMORROW'S design of any large and costly piece of electrical apparatus will be based upon the validity and accuracy of today's test data. It is not practical to build a significant number of power transformers, for example, to establish an optimum design since there is no single optimum to meet all conditions. Reliance must be placed on data obtained from tests on current production to guide the best of engineering skills. Testing tolerances must be kept low for *each piece* of apparatus rather than to place dependence upon the average results.

In a broad sense, testing tolerances are established by the care in selecting and maintaining instrumentation, and by the degree of stability of the voltage and frequency of testing power. There is little to be gained by providing more accurate instrumentation if the voltage and frequency fluctuates more than 0.1 percent. This is the basis for developing a means of stabilizing test power for heat runs, core loss, and impedance measurements well within the desired value. It paves the way for the application of more accurate instruments which are now being made available.

REQUIREMENTS

Any power control system that is to be applied to production testing must meet certain requirements other than the required degree of stability alone.

These are:

(1). Safety to personnel
(2). Ease of adjustment
(3). The required voltage range
(4). The required frequency range
(5). Applicability to existing motor-generators.

It was found that there were systems that would meet some but not all of these specifications. For example, a tuning-fork-controlled motor-generator is available whose frequency can be maintained to an order of magnitude better than the control system to be described. However, the frequency held is, and can

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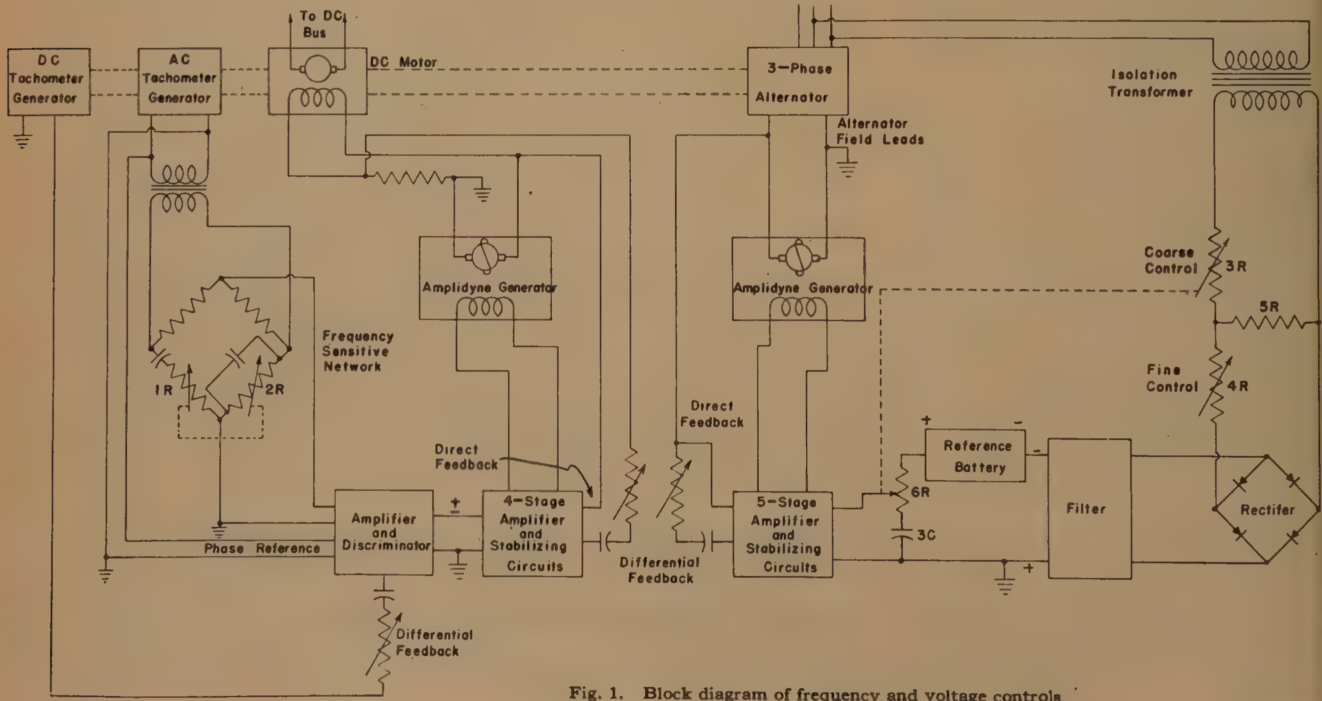

Fig. 1. Block diagram of frequency and voltage controls

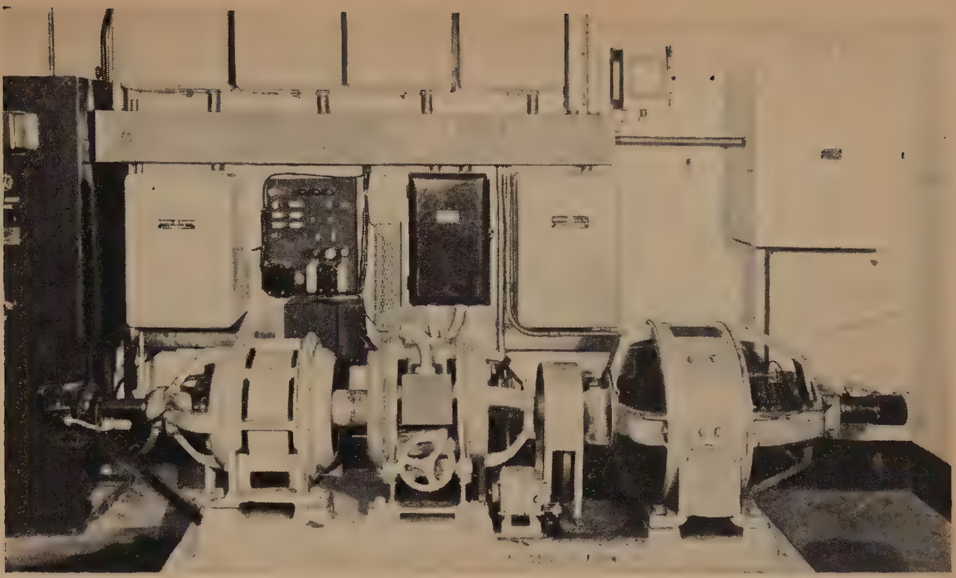

Fig. 2
Motor-generator
and control panels

only be, the resonant one of the particular tuning fork used. Continuously adjustable frequency in such cases is impossible. Furthermore, it requires a large tachometer generator which makes the system difficult to apply to existing motor-generator sets.

GENERAL

The frequency- and voltage-control system developed to meet all of the specifications satisfactorily was made possible by the amplidyne generator.(1) In principle, the amplidyne is an externally driven d-c generator. Its field current can be supplied by receiver-type electronic tubes, so that milliwatts will control kilowatts.

The complete system is given in block-diagram form in Fig. 1. The frequency control is to the left and the voltage control to the right. A view of the motor-generator with the control panels above it is given in Fig. 2. The motor-generator, which was used in developing the control system, is a 5-kva three-phase generator driven by a 7.5/16-hp 750/1800-rpm direct-current motor. The test table where all connections from the generator and the frequency and voltage adjustments are located is shown in Fig. 3.

FREQUENCY CONTROL

Frequency control is accomplished by a closed loop system using an error signal to make the necessary corrections. As indicated in Fig. 1, the d-c motor drives two tachometer generators as well as the power generator. The armature of the motor is supplied from a fixed 125-volt shop circuit maintained by a Diactor voltage regulator. The field current is used to control motor speed as directed by the error signal. The output frequency of the a-c tachometer, which is proportional to the speed, is applied to two terminals of a Wien bridge.(2) The bridge is so adjusted that it is balanced at the desired frequency. Any unbalance indicates that the frequency is either too high or too low. The unbalance voltages differ by 180 deg in phase re-

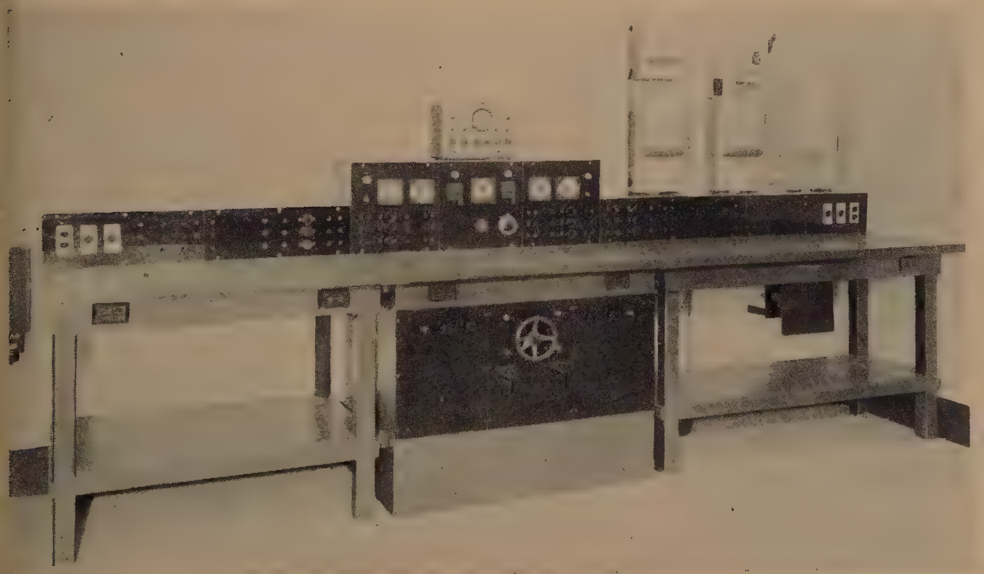

Fig. 3. Test table

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(1) Numbered references are listed at the end of the article.

lation for the two conditions. The phase relation of the unbalance voltage with respect to the tachometer voltage is minus 90 deg and plus 90 deg for the two cases.

The output signal from the Wien bridge is introduced into the discriminator and compared with a signal from the tachometer which has been shifted 90 deg in phase. A d-c voltage is obtained from the discriminator, the polarity of which will depend upon the phase relation of the bridge unbalance voltage.

The voltage is amplified in a three-stage direct-coupled amplifier which controls a fourth power stage. The power stage controls the field of an amplidyne generator which in turn controls the motor field. The polarities are so arranged that an unbalance of the Wien bridge due to low frequency causes the motor field to be weakened. The motor field is strengthened when frequency is too high.

Schematic circuits of the discriminator with its preamplifiers and the four-stage direct-coupled amplifier with stabilizing circuits are given in FIGS. 4 and 5.

Actually there will be an error in frequency to supply current to the motor field. To make the error negligible, relatively high gain must be used. Any closed loop system should satisfy the conditions that gain in the loop is less than unity when the phase shift at any frequency reaches 180 deg. If these conditions are not met, regenerative feedback takes place and the system oscillates. Phase shifts or time constants appear at many places in the loop, but principally in the inertia of the rotating parts of the motor generator, and in the inductance of the motor field.

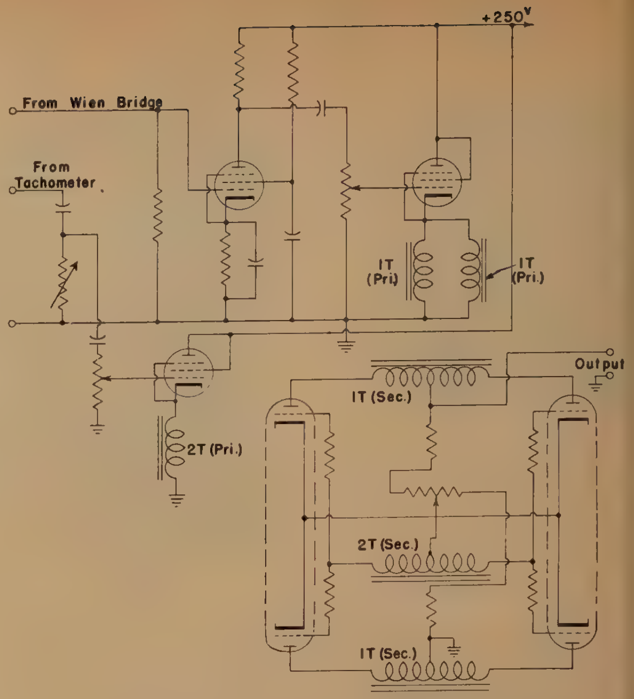

Fig. 4. Schematic circuits of preamplifier and discriminator

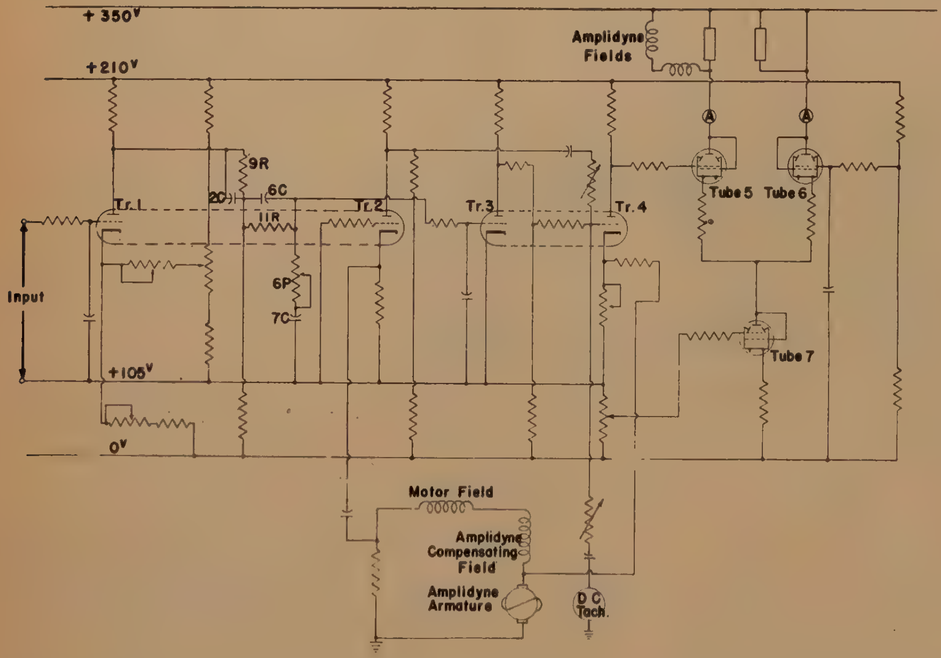

Fig. 5
Direct-coupled amplifier and stabilizing circuits for frequency control

It is beyond the scope of this article to go deeply into the theory of the methods by which hunting was eliminated since many books⁽³⁾⁽⁴⁾ have been written on this subject. It was found that stabilization, while still retaining satisfactory loop gain, could be obtained by means of a stabilizing circuit consisting of a phase-shift network and three feedback loops in addition to the principal one. The stabilizing circuit is used to connect the plate of triode *1* (Tr. *1* in FIG. 5) to the triode *3* grid. It consists of resistors *9R*, *11R*, and *6P* and capacitors *2C*, *6C*, and *7C*. It provides phase shift and attenuation at frequencies at which the system tends to oscillate. Differential feedback from a d-c tachometer generator proportional to the rate of change of speed is introduced at the grid of triode *4*. This particular feedback limits the rate at which field current can be changed. The time constant due to motor field inductance is reduced in two ways; a resistor is placed between the amplidyne and the field, and the transient voltage drop across the resistor, which is proportional to transient field current, is fed back to the triode *4* grid after being amplified by triode *2*. An additional feedback from the amplidyne armature to the cathode of triode *4* completes the necessary stabilization.

A motor-generator used for power transformer testing ordinarily does not have sudden or transient loads applied to it. However, since the transient response of a closed loop system is a good measure of its inherent stability, such an investigation was made. It was found that when full load was applied suddenly to the generator, the transient conditions were damped out in less than 0.5 sec. A Lissajous figure formed on a cathode-ray oscilloscope screen by comparing a tuning fork signal with the generator voltage merely shifted 90 deg and became stationary again.

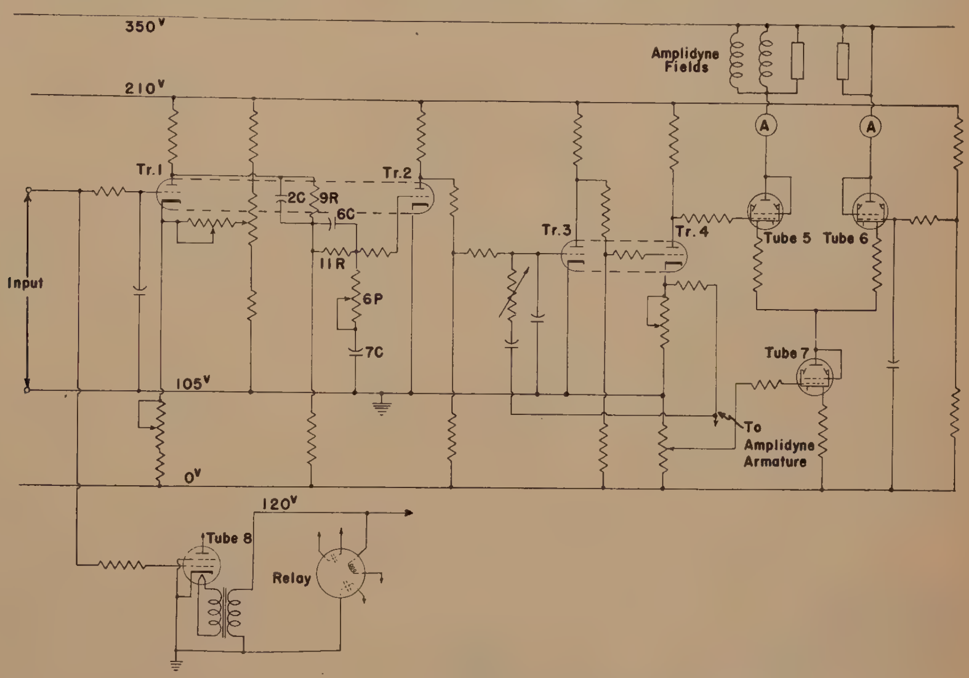

Fig. 6. Direct-coupled amplifier and stabilizing circuits for voltage control

The motor so far has been assumed to be running at the proper speed. The problem of starting the motor did not turn out to be as difficult as at first anticipated. The motor had originally been started by applying full field and automatically connecting the armature to shop circuit through progressively lower values of resistance. This method has been retained. Starting the motor-generator so far as the operator is concerned is extremely simple. A button is pushed. This operation supplies voltage to the electronic equipment, the induction motor which drives the amplidyne generator, and a timing circuit. At the same time the direct-coupled amplifier is disconnected from the discriminator and connected in such a manner that, when the tubes warm up, full field is applied to the d-c motor. A current relay is connected in the field circuit and interlocked with the timer. If at the end of the timing cycle the field current relay has pulled in, the motor armature is connected to the shop circuit through the starting-box resistor. As the last of the starting-box resistance is automatically cut out, a relay connects the direct-coupled amplifier back to the discriminator. Field current immediately drops and the motor begins to accelerate. Field current is prevented from dropping so low that the armature current becomes excessive by means of the differential feedback from the d-c tachometer. The motor cannot accelerate faster than this feedback dictates.

After the generator is running, speed can be adjusted as desired by means of tandem-operated resistors *1R* and *2R* of the Wien bridge as shown in Fig. 1. Design of the particular motor used limited the frequency range to 20–65 cycles.

VOLTAGE CONTROL

The voltage control is given in block diagram form at the right in Fig. 1. Like the frequency control, it employs a closed loop system working on an error signal. The voltage of one of the three phases is connected to a selenium bridge rectifier through an isolation transformer and resistors *3R* and *4R*. The rectified voltage is filtered and compared to a reference battery. Any difference in voltage is applied to a five-stage direct-coupled amplifier. The schematic circuit of this amplifier is given in Fig. 6. The last stage of the amplifier supplies the amplidyne generator with field current. The amplidyne is used to excite the alternator field. Polarities are so selected that, if the filter output voltage is higher than that of the reference battery, the alternator field current is reduced. Field current will be increased if the reverse is true.

Coarse control of voltage is obtained (Fig. 1) by adjusting rheostat *3R* which forms a voltage divider with *5R*. Fine control is obtained from *4R* which forms a voltage divider with terminating resistors of the filters. It will be noted that the two voltage dividers

(Concluded on following page)

CONTROL FOR STABILIZED TESTING POWER

(Continued from preceding page)

also are attenuators to loop gain. The gain is highest when minimum generator voltage is being maintained. When maximum generator voltage is held the gain is lower by the ratio of the maximum to minimum voltage. The change in loop gain was compensated by a gain control formed by capacitor *3C* and rheostat *6R* which is ganged with *3R*. Using the combination results in constant gain at frequencies at which the system would tend to oscillate. The capacitive reactance of *3C* is made low with respect to *6R* at these frequencies to minimize phase shift.

As in the frequency control, high loop gain is needed to make the required error negligible. Oscillation was prevented in a manner similar to that described for the frequency control. The stabilizing circuit is located between triodes *2* and *3* in FIG. 5. A portion of the amplidyne voltage is fed back to the cathode of triode *4* and the transient amplidyne voltage changes to the grid of triode *3*. The transient response of the voltage control is approximately that of the frequency control. In fact, the test cited for the frequency control included the voltage control in it since the two responses were not separated.

Voltage range of the generator using the control is 50 to 150 volts. The limitation in voltage range was imposed by generator design. Stability of control will always be the greatest at the highest voltage. The fine control covers a range of approximately one volt at 120 volts.

A "fail-safe" relay protects the generator against over-voltage in case of tube failure. The error voltage is applied to the grid of a thyratron (tube *8*, FIG. 6) in addition to the grid of triode *1*. The circuit has been polarized in such a manner that, as the generator voltage increases, the voltage to these grids becomes more negative. Operating normally, these grids are within a few millivolts of zero. An abnormally high voltage sufficient to cut off the thyratron (1 or 2 volts) causes a relay to drop out and interrupt the current to the amplidyne field. The arrangement fails safe because if the thyratron ceases to function the relay will be in the high-voltage position.

★Money-saving, handy, midget power resistors for tight spots and point-to-point wiring. Take place of cumbersome and costlier bracket-mounted resistors.

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ACCURACY

The power control system described in this article has a short-time maximum deviation of less than 0.01 percent for both voltage and frequency. It will remain stable to within 0.1 percent over many hours of use.

DESIGN PROBLEMS

The article has dealt mainly with the theory of operation. There are practical problems suggested by the following brief statements: The stability of the Wien bridge will be no better than its components. The rectifiers and voltage dividers in the voltage control should not contribute temperature or self-heating errors. The direct-coupled amplifier must drift less than the desired stability requirements. End play in the motor-generator, or an exciter if used, must not cause voltage variations so large that all of the loop gain is used up in correcting for these variations. The voltage reference should be chosen with care. The voltage stability can be no better than the reference used.

CONCLUSIONS

Testing power with high stability is now possible. All control adjustments can be made of small components which are easy to manipulate. The voltage and frequency ranges are limited only by the motor and generator design. Voltage and frequency controls can be readily applied to existing motor-generators.

ACKNOWLEDGMENT

The authors would like to acknowledge the helpful suggestions and co-operation of Orin W. Livingston of the Control Engineering Division of the General Electric Company at Schenectady (N. Y.).

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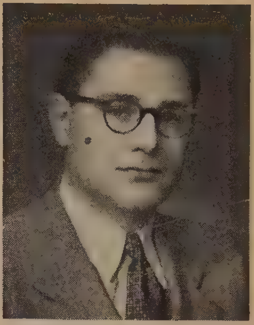
THICKNESS GAGING BY RADIATION ABSORPTION METHODS

C. W. Clapp

A review of some of the design techniques now applied to gages which measure thickness by radiations of x-rays, beta rays, or gamma rays

By Dr. C. W. CLAPP and S. BERNSTEIN
General Engineering and Consulting Laboratory
General Electric Company



Stanley Bernstein

THE fact that ionizing radiations such as x-rays, beta rays, or gamma rays experience absorption in their passage through matter has recently found application in a variety of thickness-gaging equipments (1)(2)(3)(4). In such equipments, the material to be gaged is inserted between the source of radiation and a suitable radiation detector. For a given kind of material, the output of the detector can then be calibrated in terms of the thickness of material.

SOURCES

X-RAYS

X-rays are produced by allowing a beam of high-speed electrons to fall on a target consisting of some heavy element such as tungsten. For this purpose, specially designed x-ray tubes are available containing a hot-cathode element, to supply electrons, and a target anode. The electrons emitted by the cathode are accelerated toward the anode by application of a high voltage between the electrodes. The intensity of the x-ray beam, or quantity of x-rays, is a function of the number of electrons that strike the target, which is in turn controlled by the cathode filament current. The wave length, and therefore the absorption characteristic of the x-rays, is controlled by the cathode-to-anode potential, which in thickness gages normally lies between 25 and 150 kv.

In FIG. 1 is shown a set of absorption curves for x-rays in steel, which include x-ray tube voltages as a third variable. It will be noted that, over the voltage range shown, the penetrating power of the x-rays increases with anode voltage.

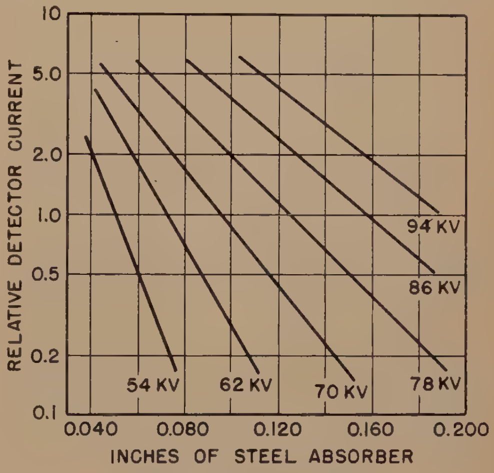
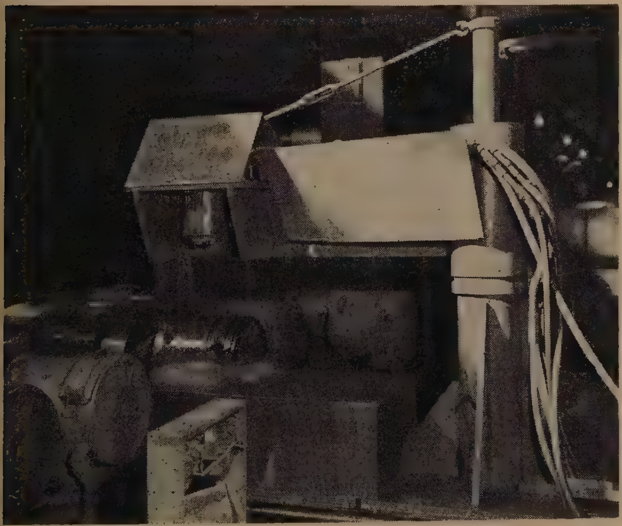


Fig. 1. X-ray absorption curve

The curves indicate two significant factors which will affect the design of an x-ray thickness gage. The first is the effect of changes in x-ray tube voltage. It can be seen that, at 78 kv and 100 mils of steel, a 1-percent change in voltage will produce the same change in detector current as will a 2.8-percent thickness change.

The second factor is found in the effect of the change of detector sensitivity, or strength of x-ray beam. At the same point in the curves shown in FIG. 1, a 1-percent change in either sensitivity or beam strength will have the same effect as only a ⅓-percent change in thickness. At constant voltage, however, as the thickness is reduced, these changes will produce greater errors, limiting the lower end of the thickness range for that voltage.



Installation on runout table of a hot-strip mill. The x-ray beam passes from the tank within the rectangular housing and through the hot strip to the cylindrical top detector supported above the sheet

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

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(1) Numbered references are listed at the end of the article.

It is found that as the voltage on an x-ray tube is reduced, the strength of the beam is reduced very rapidly. This effect, coupled with the limitation mentioned in the preceding paragraph, serves to limit the lower end of the useful thickness range of an x-ray thickness gage. The upper end is limited by voltage-breakdown considerations.

BETA AND GAMMA RAYS

Two types of radiation, emitted as part of the disintegration process in radioactive materials, have been used for thickness gaging: beta rays, which are electrons traveling at high speeds; and gamma rays, which, like the x-rays mentioned above, are electromagnetic in character. Radioactive materials form compact, relatively inexpensive sources of these radiations, with the added feature of producing a beam which is stable in regard to the average energy carried by each particle, or photon. In the case of many materials having long half-life, as used in radiation thickness gages, they are also stable in regard to the average number of particles emitted per second. The source consists of a small quantity of radioactive material deposited in such a way that the beam leaves with little fixed absorption. Precautions are taken so that none of the material can escape, since ingestion of most radioactive materials is extremely harmful to the body.

FIG. 2 illustrates the absorption of beta rays, while FIG. 3 illustrates the absorption characteristics of the radiation from radium, a typical source of gamma rays.

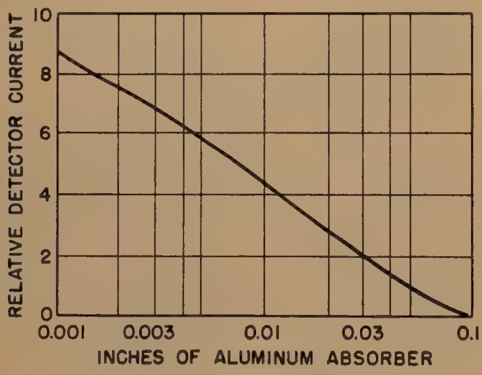

Fig. 2. Strontium 90 absorption curve

Unfortunately, there are at present no satisfactory sources of gamma rays having energies as low as those indicated for the x-rays in FIG. 1. The available gamma rays have too high a penetrating power to permit satisfactory gaging at thicknesses less than about one inch of steel.

An inspection of the curve in FIG. 2 will reveal that a 1-percent change in detector sensitivity will produce the same change in output current as a ⅛-percent change in the thickness at the thick end, and a 10-percent change in thickness at the thin end of the thickness range. Best accuracy is therefore obtained near the high end of the thickness range. The upper end of the thickness range is limited by the maximum energy of the beta rays from the radioactive materia in use, and the lower end is limited by detector stability

NOISE

The spontaneous nature of radiation from x-ray an radioactive sources gives rise to a fluctuating detecto signal. A low-pass filter may be used to reduce th fluctuations in the reading of the thickness indicato but this will also reduce the speed of its response to change in thickness. This may be undesirable in som applications. Fluctuations may also be reduced by increasing the strength of the beam in accordanc with the equation⁽⁴⁾

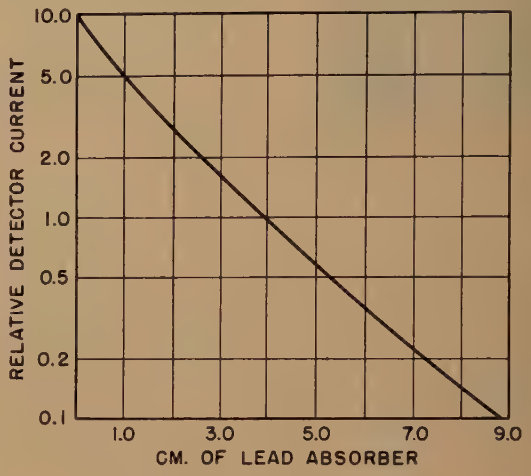

Fig. 3. Radium absorption curve

$$\frac{N}{S} \propto \frac{1}{\sqrt{TM}}$$

where $\frac{N}{S}$ = Noise to signal ratio at a certain thicknes

T = Time constant of low-pass filter assumed to consist of single R-C section.

M = Strength of source.

Increasing the source strength will also increase th radiation level around the gage. Safety consideration will therefore limit the extent to which the bean strength can be increased. A compromise must be accepted between maximum allowable source strength desired speed of response, and allowable indicato fluctuation.

SAFETY

Aside from high-voltage considerations, the chie safety requirements of an x-ray gage are that the radiation level be safe in areas accessible to operators and that the x-ray tube be properly interlocked with safety gates, etc., to prevent access to areas of high radiation level.

The use of radioactive material as a radiation source requires further that the material be permanently held in place to avoid contaminating the product, work area, or operators. The preparation of such sources requires extreme skill and attention to detail to avoid pinholes or cracks in the outer covering, through which radioactive material could leak.

DETECTORS

The three most common detectors of radiation of this type are the ionization chamber, the Geiger-Muller tube, and the phosphor-phototube combination.

IONIZATION CHAMBER

When x-, gamma, or beta radiation passes through or into a material, energy is given up by ionization of atoms in the material. If the absorbing material is a gas, the ions and electrons so produced can be collected and measured by means of a pair of electrodes maintained at a suitable difference in potential. Such a device is called an ionization chamber, and is commonly used to detect and measure radiation of this type.

FIG. 4 illustrates the effect of changing the potential difference between two such electrodes. As the voltage is increased, an increasing number of ions accumulate, until finally a plateau is reached where all the available ions are collected. Since the chamber sensitivity is relatively independent of small voltage changes on this plateau, the operating point is usually selected in this region.

For a fixed radiation field, the output current of an ionization chamber depends upon the composition and density of the gas in the chamber. Therefore, hermetically sealed chambers are used if maximum accuracy is desired.

The current from an ionization chamber is usually in the order of micro-microamperes. In order to obtain a reasonable voltage for vacuum-tube circuits, this current is passed through a high resistance of the order of 10^9 to 10^{12} ohms. Special tubes featuring extremely low grid current are then used in the first stage of the following amplifier. If the signal from the ionization chamber is amplified as direct current, then the zero drift and instability peculiar to d-c amplifiers are frequently encountered. Automatic periodic checking is sometimes employed to provide the necessary accuracy in such cases.

Where the source is an x-ray tube in a self-rectifying a-c circuit, or a radioactive material whose beam is periodically interrupted with a mechanical chopper, an a-c signal is obtained from the chamber. Because the maximum chamber load impedance is then limited by circuit capacitance, more amplification is required in the a-c than in the d-c system. However, the succeed-ng a-c amplifier is more stable, and a satisfactory system results.

GEIGER-MULLER TUBE

If the voltage on an ionization chamber is greatly ncreased, the curve in FIG. 4 will start to rise again, ndicating that the electrons are moving with such speed that they in turn produce more ions by collision with other gas molecules. At sufficiently high electrode voltages, a single electron in the chamber will start an avalanche of ionization, which will sustain itself at a high level until quenched. The Geiger-Muller tube utilizes this effect. Such a tube can be used as a counter of discrete particles, or photons.

High counting rates are required in thickness gages for minimum random indicator fluctuation. Since the Geiger-Muller tube has a short life under these conditions, its use has been restricted in this application.

PHOSPHOR-PHOTOTUBE

Certain materials are available which fluoresce under the action of the radiations described here. Among these materials are zinc sulphide, potassium iodide, and cadmium tungstate crystals. A multiplier-type phototube is used because of the small amount of light available from the phosphor.

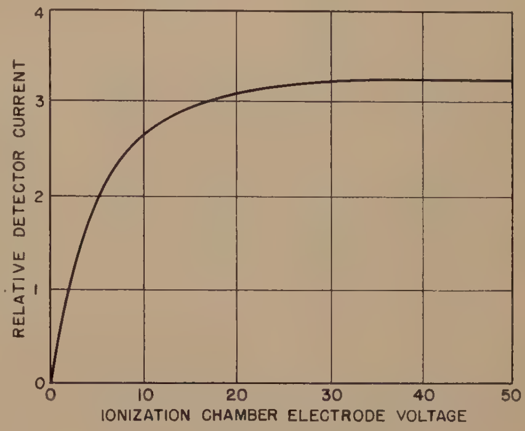

Fig. 4. Ionization-chamber saturation

The high gain of the phototube produces an output voltage many times higher than that obtained from the same radiation in an a-c operated chamber. However, the gain of the phototube is severely dependent upon its supply voltage, and it is difficult to regulate this voltage sufficiently well to obtain the accuracy usually required in a thickness gage. When comparison methods can be employed to overcome this deficiency, the phosphor-phototube combination is capable of providing a sensitive and sturdy detector.(1)

GAGING SYSTEMS

In view of the accuracy required and the limitations of the components in this respect, the problem of designing a satisfactory thickness gage is not an easy one.

X-RAY GAGES

To avoid the necessity for extremely close regulation of anode voltage and beam current, most x-ray gaging systems proposed up to this time employ two x-ray beams in a balanced-bridge, or null, system. In such a system, one of the beams passes through an adjustable reference or standard thickness of material, while the second beam passes through the material to be gaged. The transmitted portions of the two beams are then compared in a suitable detector, or detectors, whose output can be used as a measure of the thickness difference between the standard and the sample.

(Continued on following page)

THICKNESS GAGING BY RADIATION ABSORPTION

(Continued from preceding page)

In one such system(2) described in the literature, two separate x-ray sources are operated from a common supply, with the two beams converging on a single detector. Another system(1) makes use of two beams from a single x-ray source and employs two separate detectors. In both systems, the detectors consist of phosphor-phototube combinations used in a comparison circuit.

Because of the nonlinear relationship between the thickness of absorbing material and the intensity of the transmitted beam, most gaging systems require a scale-factor adjustment, which must be set at the proper value for each thickness to be gaged. This additional adjustment is eliminated in one gage system(1) by insertion of a uniformly tapered wedge of material in one of the two x-ray beams. The wedge is positioned automatically by a servo system to maintain the transmitted portions of the two beams in balance. The thickness indication of the gage is therefore derived directly from the position of the balancing wedge in linear thickness units which depend only on the taper of the wedge.

BETA-RAY GAGES

Because of the inherent stability of beta-ray sources, the advantages of a two-beam comparison system are less in evidence, and single-beam systems are commonly used. Either the ionization chamber or the phosphor-phototube detector can be used, but the latter presents problems of stability unless used in a comparison system, and is therefore less suited to this application.

One type of beta-ray thickness gage now in use utilizes a mechanical chopper over the source and an a-c amplifier.(4) Another type currently available uses a d-c amplifier with automatic periodic calibration check.(3) In both systems, a voltage applied at the amplifier input to buck out the signal from the chamber provides a null system for deviation indication.

Comparison of X- and Beta-ray Gages

In general, the beta-ray gage will give superior accuracy at 0.001 in. of steel or less, and becomes a compulsory choice for 0.001 in. or less of aluminum, paper, etc. In the range from 0.001 to 0.050 in. of steel, both types of gage are useful, the beta-ray gage being more compact and less costly, while the x-ray gage permits the use of deeper gage throat openings and faster gage response. In the range from 0.050 to 2 in. of steel, approximately, the use of x-rays is indicated, since no beta-ray sources exist with sufficient energy to produce reasonable signals. In the range above approximately 2 in. of steel, gamma rays should prove useful.

Beta-ray absorption depends essentially on the weight per unit area of the absorbing material, while x-ray absorption depends also upon its chemical composition. Therefore, where the chemical content of the material to be measured is not controlled, the effect c these variations should be considered before specifyin an x-ray gage for the application.

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STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912 AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946

Of General Electric Review published monthly at Schenectady, Ne York, for September 28, 1950.

State of New York }
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Before me, a Notary Public in and for the State and county aforesai personally appeared E. C. Sanders, who, having been duly sworn accordin to law, deposes and says that he is the Executive Editor of the Genera Electric Review and that the following is, to the best of his knowledge an belief, a true statement of the ownership, management (and if a daily, weekl semiweekly or triweekly newspaper, the circulation), etc., of the aforesai publication for the date shown in the above caption, required by the act c August 24, 1912, as amended by the acts of March 3, 1933, and July 2, 194 (section 537, Postal Laws and Regulations), printed on the reverse of th form, to wit:

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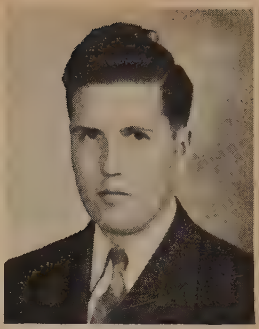
Sworn to and subscribed before me this 28th day of September 1950.

Dorothy Anne Dumbleton
Notary Public, State of New York
Schenectady County
My commission expires March 31, 195

[SEAL]

HERMETIC SEALING OF AIRCRAFT INSTRUMENTS

Extended use of aircraft and their required flight in all types of weather increases the importance of maintaining instrument reliability and accuracy by protection against adverse atmospheric conditions. How hermetic sealing is advantageously used to give such protection



By R. F. BUCKLEY

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R. F. Buckley

UNTIL recent years, aircraft instruments were useful as an aid to visual navigation and for checking operating conditions of various components of the plane. Now, however, the safe flight of an aircraft is primarily dependent on proper instrument operation. Military-aircraft operations have been extended to the four corners of the earth and to the upper reaches of the stratosphere. At the same time commercial-airline routes have been expanded to provide service in hemispheres where all possible conditions of temperature, pressure, dirt, and humidity exist. Because these planes are required to fly in all types of weather, the importance of instrument reliability and accuracy has been greatly increased.

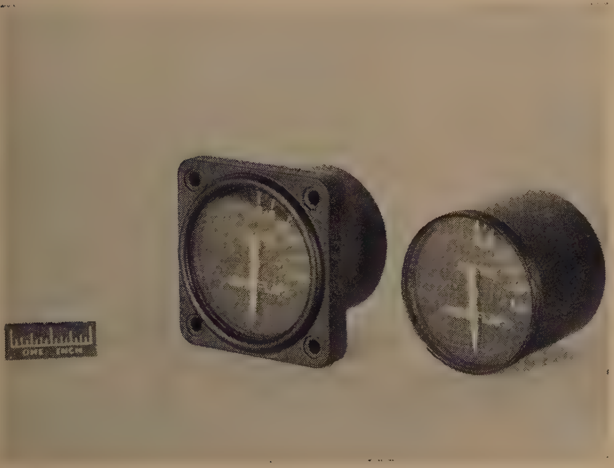

Fig. 1. Hermetically sealed position indicators

The greatest single factor in maintaining reliability and accuracy in an instrument is the amount of protection offered the instrument mechanism against the effects of the atmospheric conditions just mentioned. Nearly all mechanisms include some type of very low-friction moving system which may be rendered entirely inaccurate or disabled by a dirt particle or piece of rust. Fungus growths(1) will attack organic insulating materials, obscure dials, and foul electrical contacts. Moreover, low ambient pressure at high altitudes increases the danger of insulation breakdown across necessarily small leakage paths.

HERMETIC SEALS

The hermetically sealed case is the most practical method of providing complete protection against adverse ambient conditions. This type of construction, more commonly associated with the evaporated milk container or the electric light bulb, offers the advantage of controlled pressure and humidity, and laboratory cleanliness. With a gas-and-moisture-tight case, the interior can be evacuated and filled with a dry gas such as helium. The use of such a gas has several advantages, namely: the lack of moisture precludes the danger of fogging, or moisture condensation, on the window glass; the temperature rise in electrical instruments is reduced; and the electrical breakdown potential is increased. Gyroscopic instruments embodying masses rotating at high speeds also gain the added advantage of faster acceleration through choice of the proper filling gas.

Laboratory tests run on one type of gyro compass showed a reduction of 53 per cent in temperature rise and 19 per cent in acceleration time merely through substitution of helium for air as the ambient gas.

Hermetic seals are required at four junctions in an instrument case: the window-glass joint; the case-to-back-cover joint; the electrical connections; and the junction of rotary-motion shafts such as reset or adjusting shafts. A description of a sealed instrument will illustrate the types of seals used at these four junctions.

SEAL DESIGN

The size and functional requirements of aircraft instruments are dictated, to a large extent, by Air Force and Navy specifications. These specifications are continually being revised to provide improved instrument accuracy and reliability. The number of instruments required on a plane panel also makes it necessary that the indicators be made smaller, lighter, and more easily readable.

FIG. 1 illustrates an instrument designed to meet a specification for hermetically sealed position indicators. The instrument is furnished both with and without a

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(1)Numbered references are listed at the end of the article.

cover flange, thus permitting mounting on the two types of instrument panels now in use.

Case Seal

The small 1⅞-in. diameter case required by specification led to the development of the case seal shown in Fig. 2. The main section of the case is a one-piece tube, and the back cover is a flat plate with a flanged edge. The instrument mechanism is mounted on posts which are staked and soldered into the back plate. Supporting springs are placed at a forward mounting plate in longer instruments to prevent excessive stress concentrations at the solder joints. These springs hold the forward section of the instrument firmly in position; they resist vibration and shock, and yet permit easy removal from the case.

Window-glass Seal

Proper readability of such a small instrument demands that the dial be as large as possible with a minimum of space allowed for the seal. A simplified but sturdy window-glass seal which reduces only slightly the available dial area is obtained by joining the glass directly to the case. This is accomplished by applying a platinum paste to the glass, and fusing the two in an oven. The resulting metallic coating on the glass is tinned with solder, after which normal soldering procedure is followed to join the glass to the case. There are in existence many methods of joining glass to metal,(2) but few are as suitable for large-scale production as the platinum-paste method chosen. This method requires no intermediate space-consuming bezel, no special glass, and no special case metal. Neither does it require prior oxidation of the metal surface to be joined. The soldering procedure is also much simpler and easier to adapt to conventional instrument manufacturing than other fusing operations involving softening and possible distortion of the glass.

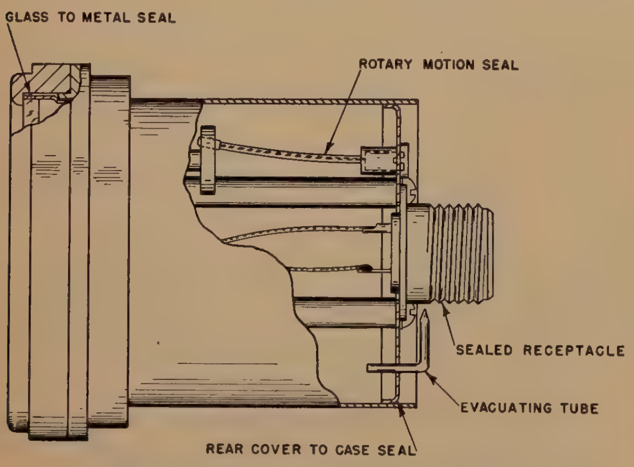

Fig. 2. Diagram showing hermetic-seal design of instrument case

Receptacle Seal

The electrical receptacle consists of a metal shell, some glass insulating beads, and the connector pins. The glass beads are fused to the pins and to the shell making an air-and-water-tight seal. This unit is then soldered to the rear mounting plate of the instrument.

Rotary-motion Seal

A seal capable of transmitting rotary motion is required on those instruments embodying internal adjustments. Some of the more common of these adjustments are: zero resets on cyclometers; gyro caging; scale calibration adjustments; and adjustable dials. In aircraft, where space and weight are both at a premium, the seal must be small and light. Such a seal has been developed and an illustration of its use is shown in Fig. 2. The unit consists of a bent wire which is inserted in a flexible metal tube, one end of which is closed. The open end of the tube is brazed to the back plate, with the end of the bent wire extending from the case. This end of the wire has a slotted head for screw-driver adjustment. The bent wire causes the tube to bend into an arc and, as the slotted head is rotated, the closed end of the tube describes a circle. This end of the tube acts as a drive finger to rotate that portion of the mechanism requiring rotary adjustment. The device is inexpensive, compact, lightweight, and capable of transmitting sufficient torque for all intended instrument applications.

Evacuating Tube

The size of the evacuating tube is critical, because it must be large enough to evacuate and refill the instrument interior in a relatively short time, yet it must not exceed the dimensional requirements of the instrument specification or be objectionable in appearance. Since the time for evacuation varies approximately as the inverse of the diameter cubed, it is possible to set a minimum tube size based on the longest acceptable time for the evacuation cycle. The tube chosen for the small-size instrument design shown in Fig. 1 has a 0.073-in. inside diameter which permits evacuation in six minutes and also meets the space and appearance requirements.

SEAL TESTS

The sealed instrument is required to pass stringent leak tests as well as functional tests of the instrument mechanism. To insure that completed instruments will pass the seal tests, each subassembly seal is checked upon completion by applying air pressure to the seal while it is held under water. Leaks are evidenced by escaping air bubbles in the water. After the completed instrument is similarly tested, it is evacuated, flushed with dry helium, evacuated again, filled with helium, and the final seal made on the evacuating tube. These tests are merely preparatory to the actual seal tests required by government specifications, which consist of a vacuum test and a thermal-shock test.

Vacuum Test

The vacuum test consists of immersing the instrument in water and reducing the absolute air pressure above the water to 2½ in. Hg. Because the pressure inside the sealed case is approximately 30-in. Hg, a leak can be detected by watching for escaping gas bubbling up through the liquid. A mass-spectrometer leak detector(3) gives a far more sensitive indication of leaks than this method, and this type of equipment is used on high-production instruments.

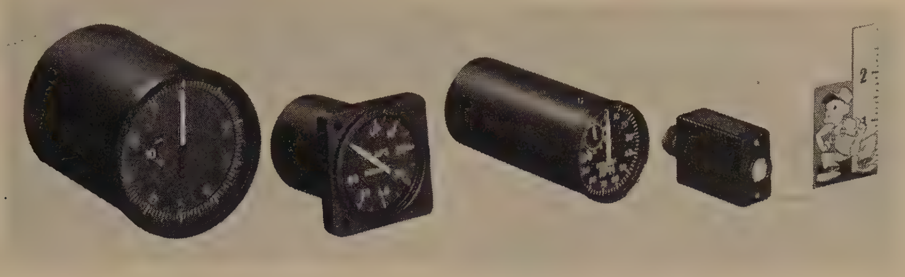

Fig. 3. Representative types of hermetically sealed instruments

Thermal-shock Test

The thermal-shock test is a more severe requirement, since it specifies that the instrument be subjected to 15 temperature cycles, each consisting of alternate 30-min. submersions in water baths at 85C and at zero C. The time of transfer from one bath to the other is limited to a maximum of 5 sec. Upon completion of the 15 cycles, the instrument is examined for seal damage and moisture penetration, and the test for leaks repeated. Instruments of the design described have successfully passed this examination after 30 temperature cycles.

Environmental Tests

In addition to these seal tests, the instrument design meets the requirements of three environmental tests:

(1). Salt Spray—50-hr subjection to salt spray

(2). High Altitude—1-hr operation with external pressure of 0.82 in. Hg absolute

(3). High Altitude, Low Temperature—4-hr instrument operation at an absolute pressure of 3.44 in. Hg and at a temperature of −55C.

CONCLUSION

The hermetically sealed case design as described and illustrated meets the Air Force-Navy sealing and climatic tests. The case-seal design offers all the advantages of hermetic sealing, namely:

(1). Simple case construction
(2). Small size
(3). Longer instrument life
(4). Reduced maintenance
(5). Greater instrument reliability
(6). Elimination of window-glass fogging
(7). Lower temperature rise
(8). Decreased windage losses for rotating parts
(9). Higher electrical breakdown potential.

Recognition of these advantages has led to the ever-increasing application of hermetic sealing to the redesign of existing instruments and to new instrument designs. FIG. 3 shows representative types and sizes now being sealed. The four types of seal joints presented here should prove of value not only in aircraft-instrument designs but in all instrument types, control devices, and other units requiring protection against damaging operating conditions.

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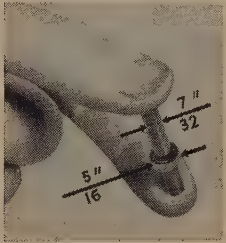

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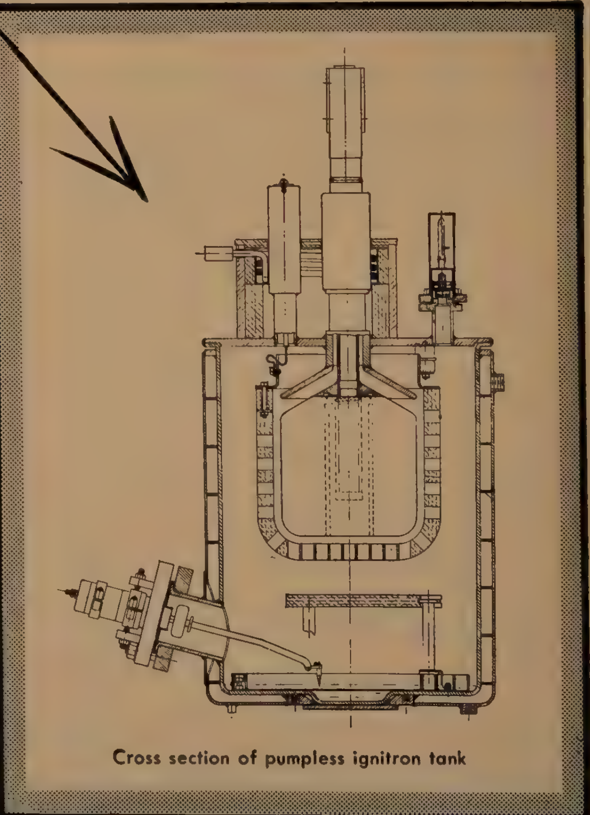

Cross section of pumpless ignitron tank

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U. S. Pat. 2,181,076

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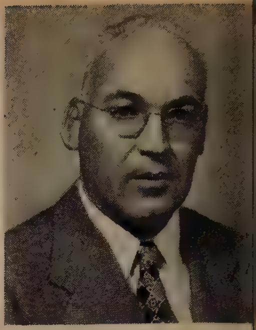
MEASUREMENT AND CONTROL OF BULK DENSITY



William T Rawl

Use of a "density characterization curve" for precision testing of mass per unit volume of powder where accurate control of the mass is desired for industrial purposes

By W. T. RAWLES
Chemical Department, General Electric Company
Pittsfield, Mass.

IN THE use of powders, one problem very often encountered is the control of a definite weight of powder to be introduced into such things as the cavity of a pill machine or a cavity of a mold, or into tubes or other special shapes. Examples are common in the powder-metallurgy field, the ceramic or refractory field, the molding of compounds, or in the preparation of sheathed heating units.

In most cases volumetric methods are used to control the mass of powder filling the unit space. Star- or rotary-vane feeders are used where large volumes or masses are required. Special small cups or cavities, wheels, or cylinders perform the task for large numbers of small units. Frequently the cavity or space itself is used by partial or complete filling for control of mass of powder.

In all cases it is essential that the mass per unit volume of the powder (bulk density) be constant and precisely known if accurate control of the mass is desired. The measurement of bulk density is complicated, because the degree of settling or packing of the powder is dependent not only upon the particle size distribution but also upon the method and degree of vibration used to pack the powder prior to measurement. Furthermore, in order for the method of measurement to have some meaning, it must be correlated to the filling machine in which the powder in question is used.

APPLICATION PRINCIPLES

Instead of going through the tedious and costly efforts of designing a laboratory machine to duplicate each application, or filling machine, used by different groups, it has been possible to more accurately and simply define the density properties of a powder through the use of a "density characterization curve."

It is obvious that extreme or optimum methods of vibration will cause a powder to attain its maximum density (using vibration only), while other methods will cause the same powder to settle to a much lower density. By using three or more judiciously chosen methods of vibration, it is possible to define the properties of the powder on a curve of bulk density v degree of vibration.

One powder must have the same settling propertie as another if its characterization curve duplicates tha of the other. In other words, the bulk densities of tw powders must be identical within the accuracy of th curves over the entire range of vibration methods they have the same characterization curves.

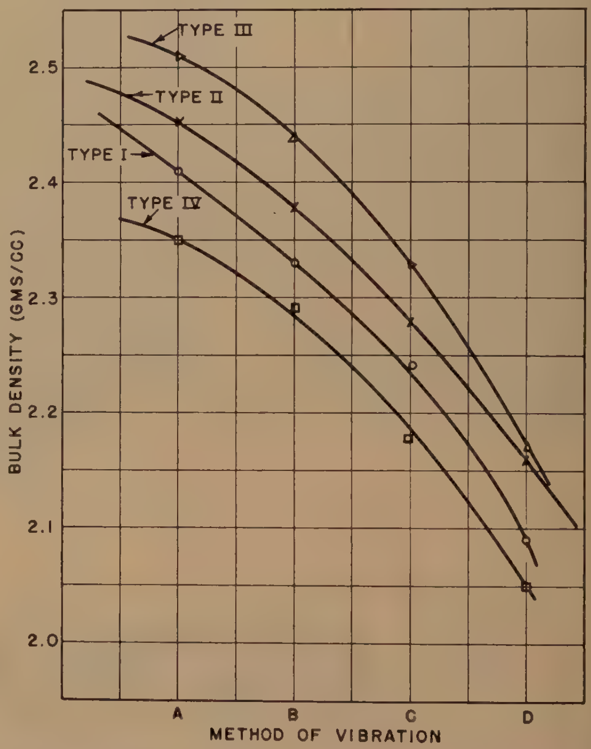


Fig. 1. Characterization curves of the bulk density of four types of fused magnesium oxide, measured by four different methods of vibration

If the methods of vibration used have been sufficiently inclusive in the determination of the characterization curve, the principle stated here will hold throughout all conditions of measurement, whether o not they are precisely known.

GENERAL DESCRIPTION

With this principle in mind, the magnesia manufacturing group in the General Electric Chemical Department used the characterization curves of fuse

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

nagnesium oxide shown in Fig. 1 for control of their roduct. In this case, the bulk density of four different owders was measured by four different methods: A, B, C, and D. Comparison of the four methods is shown n Table I. The time required to measure all four ensities does not exceed eleven minutes.

TABLE I

COMPARISON OF FOUR METHODS OF BULK-DENSITY MEASUREMENT

Method	Amplitude	Frequency (cycles per sec)	Time	Type of Vibration	Precision %
A	7.0 mils	120	3 min	Upward strike Spring return	±0.1
B	2.5 mils	120	2 min	Upward strike Spring return	±0.1
C	Variable	60	2 min	Upward strike Free fall	±0.3
D	3 inches	. . .	15 times	Free fall	±0.5

The four curves in Fig. 1 show the characteristics of he four types of powders that have been standardized o meet industry requirements. Variations within ±1 ercent are considered as duplication of properties.

Fig. 2 shows how one powder compares with another hrough the four different methods of measurement. It an be seen that Sample A and a Type II powder may e used in the same application if extreme densification hrough vibration takes place, but not at lower vibraions as in Methods B, C, and D. Sample B may be sed to duplicate Sample A powder if used in applicaions comparable to Method C in degree of vibrations. Under normal circumstances, it has been found possible o produce material duplicating the characterization urves of the standard types of powder within the ±1 ercent limit.

It can readily be seen that the characterization curve ufficiently defines the properties of the powder, eliminating the need for close correspondence between the aboratory methods and the application method. Reliance upon a single arbitrary method of density measurement that does not adequately define the properties of he powder may lead to difficulties, as shown in Fig. 2. t is true that a laboratory method may be devised to uplicate an application, but this is seldom if ever ttained and may necessitate costly equipment and edious procedures. It is essential, however, that laboratory methods be chosen which include the full range f methods of vibration beyond the most extreme application, both high and low density, and that one or ore of the intermediate methods be simultaneously pplied.

Since Method A was designed to give the highest ensity possible on any one powder by vibration alone, nd Method D about the least density through vibration, there is every reason to believe that the final machine in which production filling is taking place will fall ithin the two extremes of the curve. Therefore, when one powder duplicates another throughout the entire curve, they must behave in exactly the same manner in the final filling machine. It is not necessary to know the characteristics of this final filling machine in order to establish methods of uniformity control.

Once a powder type has been established as being satisfactory in the final filling machine and the characterization curve established, satisfactory duplication on all succeeding powders can be assured.

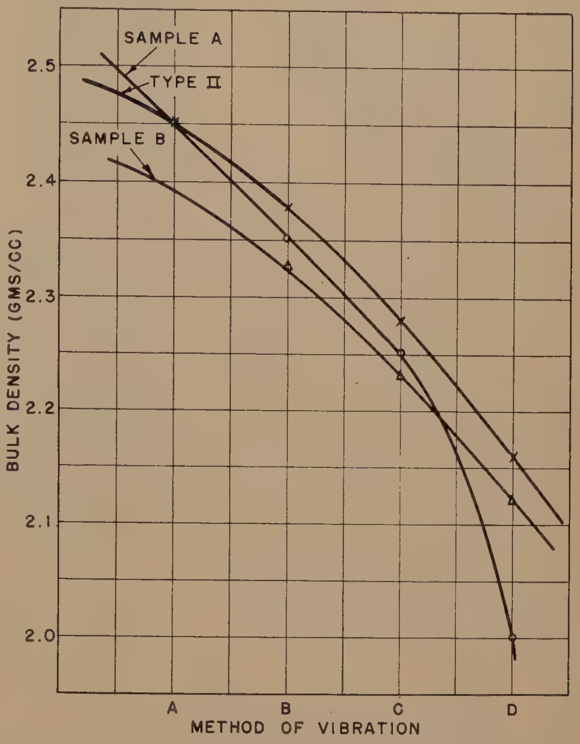


Fig. 2. **Curves illustrating choice of method in comparison of one powder with another**

Rigid control of screen analyses for bulk-density purposes only is not necessary, as there are a number of different screen analyses that will result in the same characterization curve. This permits more flexibility in manufacturing without sacrifice of density control. However, certain generalizations have been noted. The addition of the coarse fraction of the powder tends to decrease the slope of the characterization curve, while addition of the very fine dust tends to increase the slope. These facts are taken into account in the plant when it appears that a powder must be adjusted to bring its curve into line with the particular standardized type desired.

CONCLUSIONS

The settling, or density, properties of a powder have been defined by a characterization curve. If two powders have the same characterization curve, they will have identical densities by whatever method of measurement or application is used, within the limits of accuracy of the curve. The characterization curve of a powder can be readily established with the minimum of expense and time. Correlation of the curve to the application offers little difficulty.

HIGH LIGHTS AND SIDE LIGHTS

New Tension Control in Paper Making

Sectional drive equipment, replacing an old electric drive system at an eastern paper mill, will allow an increase in production speed from 700 ft per minute to 1000 ft per minute, and thus increase the company's capacity for the production of book and bond papers and sulphite specialties.

The new installation will replace a thirty-year-old drive system that uses the synchronous-tie principle, and will consist basically of nine separately controlled drive sections co-ordinated as a system, using electronics to detect speed changes and to effect immediate corrective signals to maintain proper speed relationships between sections. Each section includes a drive motor, a generator, an electronic-amplidyne system, and control panels. The only mechanical connection between sections will be the thin web of paper running through the machine. However, complete co-ordination of all sections from the couch through the presses, dryers, calenders, and reel is maintained at all speeds by the electronic-amplidyne control.

Paper tension will be closely controlled by means of a new development called the paper tensiometer, whose use here will be its first industrial application. This device is considered a revolutionary improvement in the method of controlling paper tension. The tension head consists of a small roller approximately four inches in length that rides on top of the moving paper web. Changes in the paper tension cause the roller to deflect a slight fraction of an inch, which in turn produces an electric signal proportional to the new position. This output signal is fed directly into electronic circuits that hold paper tension automatically as set, regardless of changes in any of the variables affecting tension.

Self-supervised Traffic Control

Employing a revolutionary combination of fixed-time-cycle and electronic traffic-control equipment, the city of Denver (Colo.) has launched a sweeping modernization of its entire downtown network of traffic signals and controllers.

Designed to eliminate manual adjustments and human guesswork in timing signals to handle irregular traffic fluctuations, the installation initially will include traffic controllers at 104 downtown intersections, to be supervised electronically by a master cycle selector. All controller dial units and the master selector will be remotely housed on a central control panel and individually connected to the switching mechanisms in control boxes.

Replacing a 20-year-old installati operated by a single fixed-time controll the new system is expected by designe to provide a degree of flexibility nev before achieved. In place of predetermin fixed-time cycles, any cycle timing b tween 40 and 125 seconds as well as re green light percentages will be electron cally adjusted to meet downtown traff counts, which register automatical through under-street pressure pads at fo representative intersections.

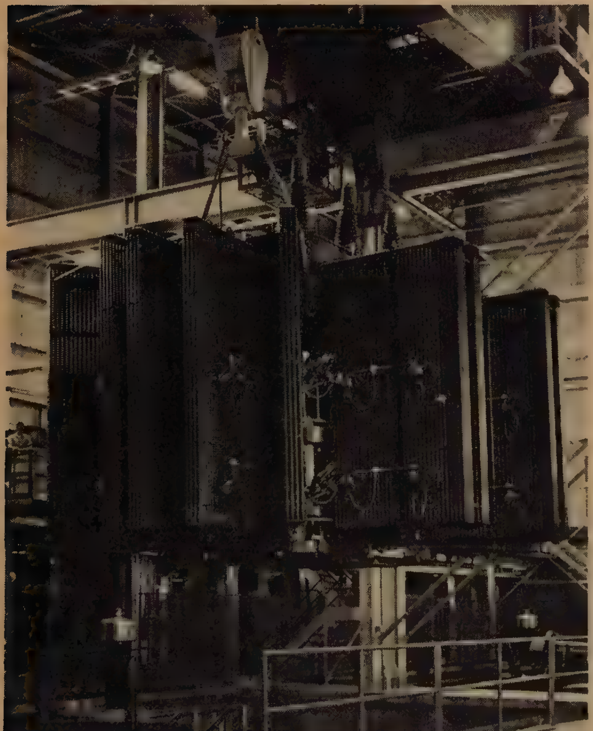
Every six minutes the electronic mast selector will add up this traffic cour compute the proper timing cycle and re green splits to handle the traffic flow, an then automatically adjust the 104 inc vidual controllers by varying the volta and frequency on their synchronous-dri motors. Adjustments of the cycle a limited to five-second increments eve six minutes to avoid sudden large chang in cycle timing.

Offsets on the controller dial units ca favor traffic entering the downtown se tion during morning rush hours and ou going traffic in the evening. In additio percentage splits of red and green ca automatically reverse between main ar side streets as traffic flow dictates. Th completely automatic traffic control w be provided at all times, regardless traffic fluctuations.

The central control panel will event ally accommodate controller dial units f 155 intersections, and the remote-contr feature ultimately may be expanded 250 key intersections.

Since the program represents a co plete reconstruction of existing contr facilities, it is expected to require abo 1½ years for completion. However, inc vidual controllers, with dial units remai ing in the control box, will be placed operation as equipment arrives.

Small as a Five-room House



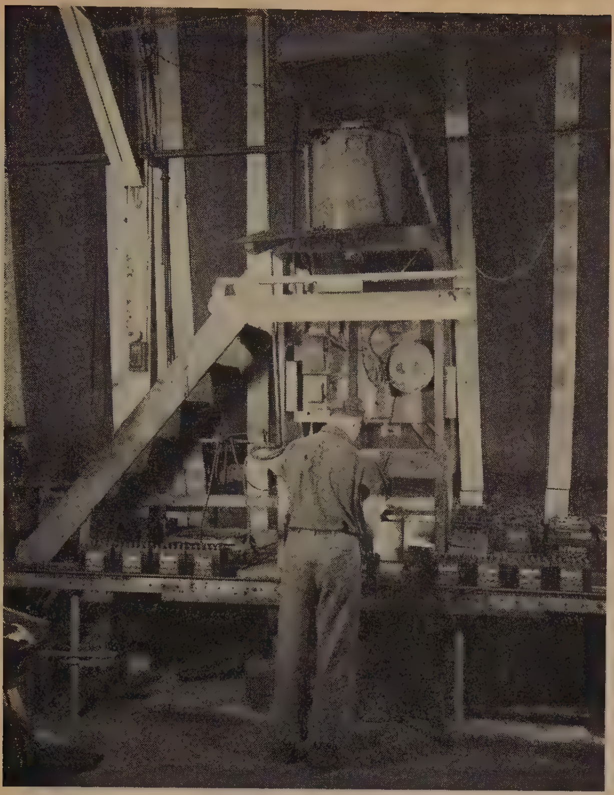
The most powerful transformer yet designed to operate at voltages as high as 138,000 volts—100,000 kva, 3 phase—is hoisted from test pit by a 250-ton crane. Until comparatively recent engineering improvements, physical dimensions of such a unit would have been prohibitive. It will be able to handle enough electricity for a community of 100,000 people

Big Scherbius Set for Supplementary Power

One of the largest Scherbius frequenc changer sets ever built will soon be i stalled in an eastern steel mill. T 25,000-kw induction-synchronous set w be used to replace 25-cycle power whi will be lost from the existing boilers as result of the increased need for proce steam.

An air-cooled continuous-rated 60- 25-cycle set, the Scherbius frequen changer is capable of delivering 25,0 kw to either end of the 25- or 60-cyc system. It has a range of 24.4 to 25 cycles on the 25-cycle system, and 59 to 60.5 cycles on the 60-cycle syste These frequencies are capable of varyi simultaneously and in opposite directio

25,000 Hours at 400 F



Calrod cast-in immersion and teel-sheathed tubular heaters pplied to these battery-sealng units have completed 5,000 hours of continuous peration, with only occasional naintenance, since installation 2 years ago. The heaters naintain asphalt-beeswax ealing compound at 400 F in anks and pipe lines, to assure ree flow

Power will be purchased from the local ower company at 60 cycles and will be onverted to 25 cycles through the use of he Scherbius frequency changer. Also, in ase of loss of power supply, the changer et can be used to convert the 25-cycle ower to 60-cycle to supply the essential oad. This type of changer was chosen ecause of the necessity to regulate the oad interchange between the two systems.

The set is equipped with a completely utomatic control for starting and synhronizing to bus. A 1200-hp 60-cycle otor is used for starting. The automatic, igh-speed load regulator is capable of ompensating for load changes through he set at the rate of 10,000 kw per second.

2½ Years Ahead of Schedule

A 33-mile community-owned railroad hich threads through picturesque Waldo ounty, in Maine, recently paid off and urned a $104,500 mortgage a full 2½ ears before the final payment came due. he mortgage covered the purchase, in ovember, 1946, of two 70-ton 600-hp iesel-electric locomotives.

In official ceremonies attended by raiload officials, guests, photographers, and ownsfolk, a check for the final payment n the new locomotives was presented to n official of a Boston bank. While the elebration went on, one of the old steam comotives was being demolished to be old as junk.

The early dissolution of the railroad's ebt was attributed to the efficient operation of the locomotives, with a direct fuel saving of approximately $19,000 a year, plus additional savings in operating costs, bringing the total closer to $20,000.

The mortgage on the locomotives was to extend for six years—from November 8, 1946, to December 10, 1952. Payment in three and one-half years saved the railroad $3,998.75 in interest.

Protection for Atomic Laboratory Workers

The presence of neutrons, which are emitted by some radioactive materials and could endanger the health of atomic laboratory workers, can now be detected by a newly developed instrument.

The device, shaped like a policeman's nightstick, is called the Neutron Counter Tube, and is expected to be useful in monitoring an area near atomic piles or laboratories before workers are admitted to the area. The counter tube will show whether neutrons have penetrated the shields installed for protection against radiation exposure. If the instrument shows that the radiation level is unsafe, increased shielding can be installed.

Basic part of the detector is the tube's lining of boron, which has a special molecular property enabling it to capture the slow-moving neutrons.

When a neutron strikes an atom of boron, two particles are exploded outward in opposite directions. These particles,

(Continued on following page)

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hitting the argon gas with which the counter tube is filled, cause surges of electricity from the wall of the tube to a wire stretched down the tube's center. Each surge of current through the wire is counted. The count is proportional to the number of neutrons striking the counter tube.

While the neutrons are said to be moving slowly when they reach the counter tube, the term "slow" is a relative one. The "slow" neutrons actually travel at a speed of about one and a half miles per second.

Simplified, More Powerful Turbosupercharger

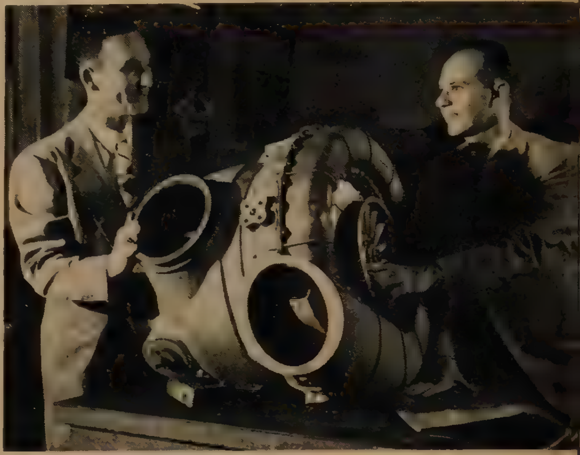
A new turbosupercharger—the CH9—making possible compound-type engines that can outperform, economically, any large power plants flying today, has been announced.

Rigorously tested on an aircraft engine of late design, the new turbosupercharger utilizes a new power cycle that simplifies the engine, at the same time adding more power. It eliminates the conventional geared supercharger, or impeller, and permits operation without clutches, gearings, or fluid disks. There are no mechanical connections between engine and turbo.

The CH9 turbo handles up to 350 lb of air per minute, compressing it to a pressure of 50 inches of mercury, absolute. With accessories, the unit weighs a total of 300 lb.

Engineering results from the actual test stand installation of the combined power plant show 32 percent more power in take-off and 20 percent lower fuel consumption than for other combinations previously tested. Average true airspeed can be increased substantially, depending on flight distance, because greater power permits flights at altitudes where turbulence and air drag are reduced.

The geared supercharger was elim nated through the development of a dire cylinder fuel injection system on t engine. As a result, the new turbo c provide full engine manifold pressu



The CH9 makes possible dramatic fuel savings together with great power increases

An aftercooler makes a net reduction cylinder intake temperature of more tha 65 percent, substantially increasing pow and safety margins.

With the new power plant a lar transport could fly nonstop from Lond to New York. On the other long fligh as from Paris to Dakar or San Francis to Honolulu, 10,000 lb or 75 percent mo payload could be added.

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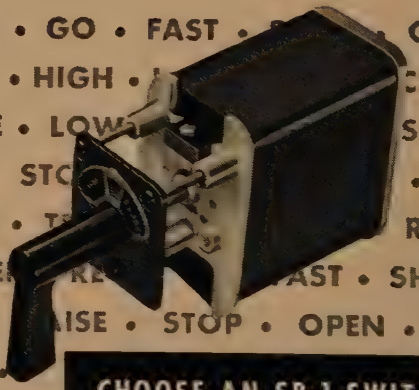

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GENERAL ELECTRIC

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Current-measuring Instrument

A new PR6-NL 1000 to 1 capacitive d-c divider, an ultra-sensitive current-measurng device for use with Model MV-17b d-c millivoltmeter. The minute currents to be measured are fed into a 500-mmf condenser or a definite period of time. A switch then ransfers the charge of the 500-mmf condenser into an 0.5-mf condenser supplying d-c power to the high-impedance millivoltmeter. Current measurements down to 5×10^{-13} amp can actually be made with a charging time of 50 sec. The device also can be used for infinite impedance voltage measurements between 1 volt and 30 kv. It then replaces sensitive electrostatic voltmeters.—*Millivac Instruments, P.O. Box 3027, New Haven, Conn.*

Protective Device

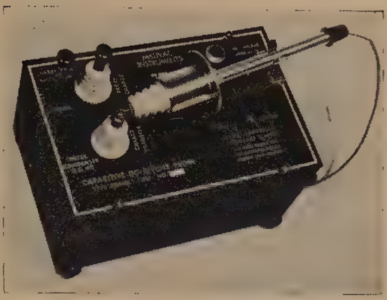
A current-limiting device, called the Amp-trap, for protection against short-circuit damage of low-voltage switchgear, bus ways, circuit breakers, transformers, and other electrical installations. The device combines high-current interrupting ability with such fast action that the current is cut off long before it can build up to dangerous levels. A 20-amp 600-volt Amp-trap, only half the size of a cigarette, can protect a feeder directly off a bus which is capable of delivering a short-circuit current of 10,000 amp. They are furnished in various types and ratings to match the electrical characteristics of old and new power installations.—*Chase-Shawmut Co., 374 Merrimac St., Newburyport, Mass.*

Core Baking Tunnel

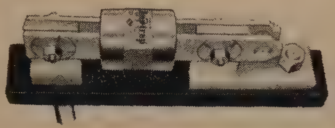
A new Ther-Monic electronic core-baking tunnel, Model M-7200, for the foundry ndustry. The tunnel bakes cores evenly throughout, with an average baking cycle of only a few minutes, having a capacity of 4 tons of cores per hour. The unit is capable of baking cores up to 60 in. wide with a maximum combined height of 20 in. for core and core plate. Conveyor speed is adjustable from 0 to about 6 ft per minute. This core-baking equipment makes it possible to adjust and control readily the green strength, hot strength, hardness, collapsibility, and other characteristics of the cores.—*Induction Heating Corp., 181 Wythe Ave., Brooklyn 11, N. Y.*

Pilot Light

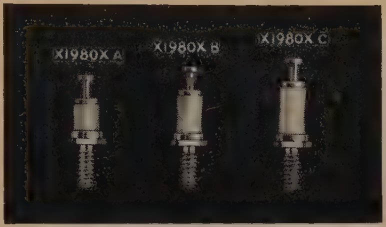
A new low-cost ready-to-install neon-type Omni-Glow pilot light designed for witchboards, instrument, and other panels. The light is completely enclosed in a plastic case. It can be mounted in a matter of econds through a ½-in. hole in the mountng surface. Maximum diameter is less than ⅞ in., making mountings as close as $\frac{13}{16}$ in. on centers when using standard speed nut which assures quick, easy, positive mountng. Maximum extension behind the panel s only 1½ in. For high-temperature applications, a special nylon housing is available. Red is the standard coloring, but other olors suitable for neon illumination are available.—*Industrial Devices, Inc., Edgewater, New Jersey.*



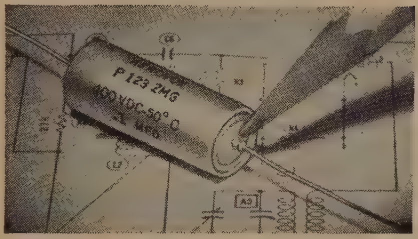
Current-measuring Instrument



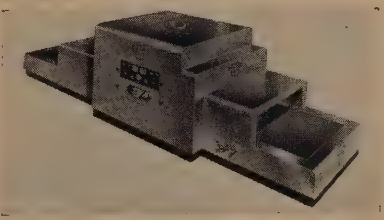
Protective Device



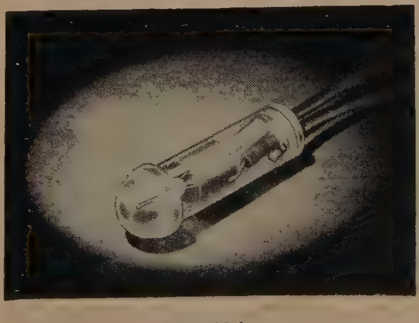
Insulated Terminals



Capacitors



Core Baking Tunnel



Pilot Light

Rectifiers

Three new magnesium-copper sulphide dry-disk Lectron rectifiers include Type H-12, a rectifier of 4- to 2-amp capacity; Type FT-12, 6- to 4-amp capacity; and Type FS-12, 10- to 6-amp capacity. The rectifiers have been designed for use in small battery chargers and trickle chargers, in addition to other low-voltage d-c power-supply applications. They are mechanically and electrically sturdy, and are unaffected by atmospheric conditions. Another feature is their instant operation from temperatures as low as −40 F to 284 F.—*Electronic Rectifiers, Inc., 2104 Spann Ave., Indianapolis, Ind.*

Insulated Terminals

Three new miniature insulated terminals combine extremely small size with excellent dielectric properties. Designed to meet the requirements of the miniaturization programs of electrical and electronic equipment manufacturers, the terminals are available in three lengths of dielectric with voltage breakdown ratings up to 5800 volts. The smallest terminal has an over-all height of ⅜ in. including terminal. Insulators are grade L-5 ceramic, silicone impregnated for maximum resistance to moisture and fungi.—*Cambridge Thermionic Corp., 462 Concord Ave., Cambridge 38, Mass.*

Capacitors

New Aerolite capacitors, Type P123ZG, of subminiature volume meet extra-severe service requirements. A marked size reduction is attained primarily by the metallized-paper section which is Hyvol K or M impregnated and placed in a nonmagnetic hermetically sealed metal case with vitrified ceramic terminal seals. Operating temperatures range from −50 C to +50 C without derating, and again at ambient temperatures up to 95 C with voltage derating.—*Aerovox Corp., New Bedford, Mass.*

Laminate Sheet

A new Fiberglas reinforced Alkyd Base Polyester laminate, known as Glastic grade MM. This grade of electrical insulation sheet stock is designed to offer at low cost such advantages as unusual arc resistance, impact strength, and low water absorption. These properties are even more apparent after exposure to elevated temperatures of 125 to 150 C. This insulation material is particularly adaptable for coil washers and spacers, slot wedges and end laminations in electric motors, as spacer sticks in transformers, and as base plates in switchgear.—*Laminated Plastics, Inc., Cleveland, Ohio.*

Speed Pulley

Stepless speed control is inexpensively obtained with a new double-groove single-belt Adjust-O-Matic pulley. A speed range of 3:1 is provided in the plastic fixture which is equipped with steel-faced sheaves and designed for drives of ¾ and 1 hp. An aluminum alloy type delivers a 2:1 range on drives of 1, 1½, and 2 hp. One important

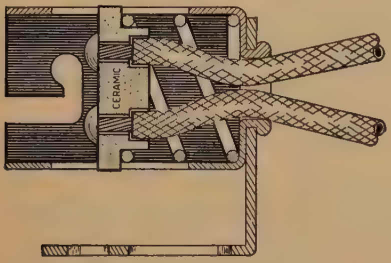
(Continued on following page)

NEW PRODUCTS (Continued)

feature of the pulley is the positive sheave location which minimizes ratio slip under varying or cyclic loads. Spacing between sheaves is set by mechanical control, which firmly holds the spacing regardless of belt wear, belt pull, or belt stretch.—*American Type Founders, 200 Elmora Ave., Elizabeth, New Jersey.*

Lamp Sockets

Lamp sockets with ceramic insulation of the new NE-12 series for mounting lamps with double-contact bayonet bases. They have UL approval and are especially suitable for the 10C7DC pilot-light lamp and bayonet-base appliance lamps. These sockets have flexible wire leads for circuit connections. The wire leads terminate inside the socket shell in contacts mounted in a heavy ceramic disk. This disk insures effective insulation of these sockets, even when hot lamps are used in them. When high ambient temperatures are anticipated, asbestos-covered wire leads can be specified for maximum resistance to the effects of heat.—*Dial Light Co. of America, Inc., 900 Broadway, New York 3, N. Y.*



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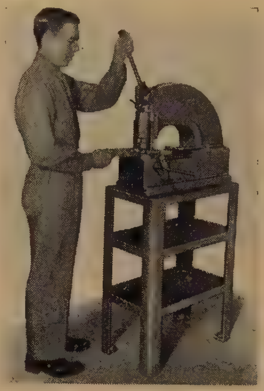
Neutron Counter Tube

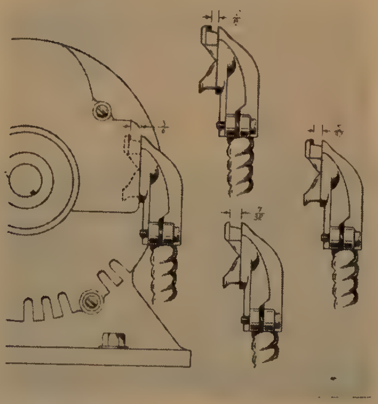
A new boron-lined proportional counter tube sensitive to thermal neutrons for use in applications of health physics and pile technology. The cathode cylinder is made from seamless steel tubing. The internal surfaces of the cylinder are coated with metallic boron enriched in the isotope boron 10 giving it a large effective area for the capture of slow neutrons. The cylinder is filled with a gas mixture to obtain self-quenching action. The counter is so constructed as to have all external high-voltage points shielded electrically and physically. Tubes of 8-in. and 12-in. sensitive length are available.—*General Electric Co., Apparatus Dept., Schenectady 5, New York.*

Precision Punch

A new Di-Acro punch No. 2 designed to provide greater throat depth than previously available in this particular line of punches. Its 12-in. throat allows working to the center of a 24-in. wide sheet. In addition to its ability to make perforations of various shapes and sizes as large as 4 in. in diameter, it also can be used as a precision punch press for a variety of blanking, drawing, embossing, and forming operations. The action of this precision machine is obtained through a roller bearing cam designed to convert a small amount of operator effort into an abundance of pressure at the point of impact.—*O'Neil-Irwin Manufacturing Co., Lake City, Minnesota.*



Cable Connectors



A new series of ⅜-in. LN (long neck) connectors for attaching armored electrical cable to ⅞-in. openings in motor housings and castings of various wall thicknesses.
These angle-type connectors are made of
special aluminum die-cast alloy of hig
strength. They can be quickly installe
after wiring has been completed, withou
need for tapping or the use of locknut
Tapping also is unnecessary when used c
curved surfaces, such as motor housing
and at the same time the connectors pr
vide maximum clearance inside the hou
ings. The connectors are made in two part
each with a grooved lip which engages th
edge and inside surface of a standar
⅞-in. opening. Operating on the simp
principle of a cam-wedge, they grip tight
when two standard machine screws a
tightened.—*Unimatic Corp., 52 East Cent*
St., Nutley, N. J.

Pull-in Elbow

A new pull-in elbow for running condu
around sharp corners without forcing
damaging the wires. It makes sharp righ
angle turns possible for straddling beams
for any location requiring a snug corner fi

The cover, easily removable, is located c
the side of the elbow permitting use c
either inside or outside corners. When th
cover is removed, wires can be pulled i
straight in either direction. This fittin
solves many difficult wiring problems an
is UL approved. It can be obtained in ½
in., ¾-in., and 1-in. sizes.—*Gedney Electr*
Co., 1270 Sixth Ave., New York, N. Y.

Hook-on Wattmeter

A new hook-on wattmeter, Type AK-
applicable to active and reactive powe
measurements in single and polyphase ci
cuits. The device makes use of a removabl
magnetic hook to surround the curren
carrying conductor, and potential leads ar
connected as in a conventional single-phas
wattmeter. In addition, a three-phase bal
ance power measurement is made possibl
by the hook-on unit. The instrument i
designed to meet exacting requirements a
to accuracy, weight, simplicity of opera
tion, and range of full-scale capacities
Through the use of a single-dial switch,
selection of any one of six power measure
ment ranges is available to provide reading
from 3- to 300-kw full-scale deflection
Measurements can be taken without servic
interruption.—*General Electric Co., Mete*
and Instrument Divisions, West Lynn, Mass

TRADE LITERATURE

Connectors—A line of pres-sure-connectors for solderless splicing and terminating of electrical wires is thoroughly covered by the detailed data, installation instructions, and ordering information. Four pages. Bulletin 750.—*Buchanan Electrical Products Corp., 1290 Central Ave., Hillside, New Jersey.*

Distribution Transformer Maintenance—A booklet titled "Maintenance Supplies for Oil-immersed Distribution Transformers" makes available to users information of practical assistance in keeping their equipment in the best operating condition at the lowest maintenance cost. Twenty-four pages. GEC-691.—*General Electric Co., Apparatus Department, Schenectady 5, N. Y.*

Electronics—Two publications on the subject of electronics: one, "Electronics at Work" describes briefly the operation of the electronic tube and its application to calculators and business machines; the other, "Fundamentals of Electronic Calculation" covers commercial and technical applications of IBM's electronic calculating machines, and describes some of the work of their Technical Computing Bureau. Twenty and twenty-four pages, respectively.—*International Business Machines Corp., 590 Madison Ave., New York 22, N. Y.*

Jig Borer and Grinder—Describes the design and operational features of the No. 2 jig borer for drilling, boring, reaming, and spotting. Action photographs show various phases of operation. Twenty-four pages. In another publication, the No. 2 jig grinder, which corrects location and finish-grinds regular and irregular contours as well as straight and tapered holes, is likewise described. Four pages.—*Moore Special Tool Co., Inc., Bridgeport 7, Conn.*

Luminaire—A presentation of Form 109 luminaire for lighting any high-speed expressway or heavy-traffic street. Its many advantages, and mechanical and maintenance features are given, aided by application photographs. Sixteen pages. GEA-5419.—*General Electric Co., Apparatus Department, Schenectady 5, N. Y.*

Materials Handling—A handbook on materials handling with industrial trucks is a practical guide for the analysis of operations and the application of the unit-load method with power-operated trucks and accessories. Sections include: types of trucks in use; unit load determinations and patterns; charging and changing storage batteries; keeping battery records; measuring handling costs; routing and dispatching methods, and training industrial truck operators. Price $1 single copies. A complimentary copy will be sent to executive officials of industry or business, and to deans and professors of engineering schools when requests are made on official letterhead. Seventy-two pages.—*Electric Industrial Truck Assn., Beury Bldg., 3701 N. Broad St., Philadelphia 40, Pa.*

Mechanical Chains—An engineering data book covering miniature mechanical chains, their application, construction, and specifications. Four pages.—*Sierra Engineering Co., 123 East Monticito Ave., Sierra Madre, California.*

Micro-gage Screens—A perusal of the folder titled "Checking 'Split-thousandths' with ESD Micro-gage Screens" will show how such measurements are made on an optical comparator. One section is devoted to fixture bases. Four pages.—*Engineers Specialties Div., Universal Engraving & Colorplate Co., Inc., 980 Ellicott St., Buffalo 9, N. Y.*

Phosphate Coating—A quick reference list of metal protective and paint bonding chemicals and processes with a comprehensive analysis of the treatment for various metals. Eight pages. Technical Service Data Sheet No. P-100-21. Available also is a Phosphate coating chemicals selection chart. Four pages.—*American Chemical Paint Co., Ambler, Pa.*

Precious-metal Alloys—Comprehensive technical and application data explains how precious-metal alloys developed for use in industrial fields are now being used for sliding contacts, brushes, wipers, slip rings, commutator segments, resistance wire, and other industrial components. Twenty pages. Bulletin R-12.—*J. M. Ney Co., 71 Elm St., Hartford, Conn.*

Shock and Vibration Mounts—A technical bulletin presenting shock mounts and vibration isolators for industrial, marine, and mobile equipment. Correlated photographs and dimensional drawings show mounting methods. Twelve pages. Catalog 504.—*Barry Corp., 179 Sidney St., Cambridge 39, Mass.*

Temperature Measurement and Control—A two-color manual titled "The Design and Process Engineer's Guide to Industrial Temperature Measurement and Control" defines the types of systems and distinguishes between them. Chapters cover the influence of the firing system on the design of the control system; fundamental tenets of mercury-bulb installation; and the basic concepts of electrical and mechanical control theory. Twenty-four pages. Bulletin No. 101.—*Partlow Corp., New Hartford, New York.*

Transformers, Reactors, Filters—A catalog containing a complete listing of UTC's line of transformers, reactors, and filters. It includes descriptions, applications, specifications, amplifier circuits, curves and charts. Twenty-four pages.—*United Transformer Co., 150 Varick St., New York 13, N. Y.*

Tungsten and Molybdenum—Text, illustrations, and tables covering: the metallurgy; physical, mechanical, and chemical properties; uses and applications; fabricating techniques, and available forms of tungsten and molybdenum. Twenty-four pages.—*Fansteel Metallurgical Corp., North Chicago, Ill.*

Vibrator Converters—A combination catalog and manual serving as a handy reference and guide to comprehensive information on Powercon vibrator converters. Twenty-two converters in five different types are described, each of which are also illustrated. Thirty-two pages. Catalog 410.—*Cornell-Dubilier Electric Corp., South Plainfield, New Jersey.*

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175	325	650	1200	1750
188	338	700	1250	1800
200	350	750	1300	1850
213	363	800	1350	1900
225	375	850	1400	1950
238	388	900	1450	2000
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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

AN INTRODUCTION TO THE GAS TURBINE

D. G. Shepherd—D. Van Nostrand Co., New York. 1949. ix+387 pp. $5.00

This is a good summary of the state of gas-turbine design in 1948, as revealed by published literature up to that time. Those who are interested in obtaining a general picture of the characteristics and problems of gas turbines for industrial, railroad, marine, and aircraft use will find that this book provides a good starting point.

The bibliography is extensive for further study. Readers in the United States may find the use of the centigrade temperature scale and centigrade heat units somewhat confusing.

D. C. PRINCE, JR.

RADAR SYSTEMS AND COMPONENTS

Technical Staff of Bell Telephone Laboratories—D. Van Nostrand Co., New York. 1949. 1042 pp. $7.50

These fifteen papers, which previously appeared in the *Bell System Technical Journal*, together constitute one of the best coverages of the subject of radar yet to appear. Even a book of this size would be inadequate to cover in detail the some sixty radar systems developed, standardized, and produced by Bell Laboratories during the war; but the present volume does much better in that, except for the first chapter, it deals with radar components, including a thorough treatment of essential theory for each item.

By such a treatment of the radar subject the reader is given the best possible education in the necessary fundamentals and is thus put in the best position to design improved components or improved systems to meet constantly advancing requirements in a far from standardized field.

The value of this material as a comprehensive reference work is well illustrated by the fact that many radar engineers have already collected the *Journal* papers in personal binders for convenient reference.

C. A. PRIEST

MEASURE THEORY

Paul R. Halmos—D. Van Nostrand Co., New York. 1950. xi+304 pp. $5.90.

Quoting from the preface, it appears that the author's main purpose in this book "is to present a unified treatment of that part of measure theory which in recent years has shown itself to be most useful for its applications in modern analysis."

The notion of measure, or "Lebesgue measure," forms a generalization of the more elementary notions of lengths and areas to more complicated loci, or "sets of points," than are furnished by ordinary curves and areas. This notion was developed in the field generally known as "theory of functions of a real variable."

The author states that "the only necessary prerequisite for an intelligent reading of the first seven chapters of this book is what is known in the United States as undergraduate algebra and analysis." This reviewer believes, however, that the ordinary college graduate who has been exposed to both algebra and analysis will find the book very difficult reading unless he has specialized in mathematics.

Of interest from point of view of applications in Chapter IX, entitled "Probability," the reader will find such terms as random variables, measure space, probability space, variance, Bayes' Theorem, Kolmogoff's theorems, the "laws of large numbers," but will be faced with the difficulties of notation and definitions introduced in the preceding eight chapters.

Summarizing, it appears to this reviewer that the present book should prove quite useful to the pure mathematician carrying out investigations in the field of measure, but will prove rather difficult reading to the reader who is interested in the applications of mathematics.

H. PORITSKY

DISSOCIATION ENERGIES AND SPECTRA OF DIATOMIC MOLECULES

A. G. Gaydon—Dover Publications, New York. 1950. vii+239 pp. $3.95

This small book primarily concerns the determination of the dissociation energies of diatomic molecules from spectroscopic data. Electron impact, thermal, and thermochemical methods are also briefly treated.

The presentation is clear and precise, and is supplemented by four photographs of spectra and 39 diagrams. Potential energy diagrams are used extensively. Conflicting methods and data are critically evaluated. A tabulation of the dissociation energies of 254 diatomic species, complete with original references and probable errors, should be particularly useful. The 516 references are complete to 1945.

The reviewer recommends this book as a reference handbook on dissociation energies and as a supplementary text on molecular spectra.

FERD E. WILLIAMS

ANALYSIS AND DESIGN OF EXPERIMENTS

H. B. Mann—Dover Publications, New York. 1950. x+195 pp. $2.95.

The primary virtue of this volume is that those mathematical methods underlying analysis of variance tests and leading to the associated experimental designs are presented in one concise exposition. Since other references on analysis of variance and of variance designs are widely scattered and frequently mathematically incomplete, this book serves a definite purpose in gathering and justifying the existing analyses of variance methods.

The mathematically trained practicing statistician will find that his appreciation of analysis of variance techniques will benefit, and the student and teacher of statistics will find that the book fills a need for completeness of instruction. The prerequisite mathematical concepts will not be so quickly grasped by the industrial experimenter, even if he is familiar with the rudiments of statistical experiment design and analysis, as the author's brief references would seem to indicate. The absence of illustrations and the virtual absence of exercises does not facilitate its individual study.

Topics include variance tests, Latin Square, incomplete balanced block, factorial and randomized designs, and the handling of nonorthogonal data. The book reaches its intended goal, that of rigorous mathematical presentation of analysis of variance topics. The extent to which this approach has appeal will depend on the reader's training and purposes.

W. C. HEALY, JR.

BIOPHYSICAL RESEARCH METHODS

Edited by Fred M. Uber—Interscienc Publishers, New York. 1950. viii+667 pp $9.50

Biophysical Research Methods has bee written to aid medical and biological scientists in applying biophysical methods t their particular problems. Eleven differen methods are described in some detail, an references are given at the end of eac chapter. Four chapters are devoted to radi biology and applications of stable an radioactive tracers. These chapters ar authoritatively written and will be of grea value to biologists interested in trace studies as well as to physicists concerne with the action of ionizing radiation upo living matter.

The book unfortunately covers only small part of biophysics, and the titl therefore is somewhat misleading.

HANS M. ROZENDAA

THE TECHNIQUE OF RADIO DESIGN (Secon Edition)

E. E. Zepler—John Wiley & Sons, Ne York. 1949. xv+394 pp. $5.00

This book is intended to convey to th reader some of the experiences of a professional designer of radio receivers. Whil the emphasis is mainly on practical desig considerations, sufficient theoretical interpretation is given at each point to sho clearly how the theory is applied. Man illustrative examples are given.

Approximately one third of the book i devoted to those performance faults whic should not happen to a first design of receiver but usually do. On such items a screening, hum, spurious beats, undesire feedback, parasitic resonances, etc., th author has provided an excellent analysis c the faults and practical cures for them.

The book covers receiver design only i the general range, 0.15 to 30 megacycles No information is given on the subjects c FM, television, communication, and rada receivers in the VHF and UHF range above 30 megacycles.

C. G. FIC

FUNDAMENTALS OF SYNTHETIC POLYME TECHNOLOGY

R. Houwink—Elsevier Publishing Co New York. 1949. 266 pp. $3.75

Dr. Houwink's fine reputation as a teacher and scientist will be increased by thi book. He has attempted to so present th basic principles of polymer technology as t enable the reader to interpret the result of tests and understand the properties c the products in the light of these principle

Basically the book outlines the organi chemistry, the physics and colloid chemistry, the properties, including standardization and testing, as well as the processing, c the polymers. Within these pages ar amassed many data and information whic can be found in no other source. The synthetic and natural rubbers are particularl well covered. The illustrations are we chosen, and the uses of the various polymers are well covered. The advantages an disadvantages of alternate processes monomer preparation make a valu addition. In the main the translatio quite smooth; the poor sentence order c the fourth line from the bottom of page 16 which gives an entirely erroneous idea is the rare exception.

The book is well documented, and the footnotes full of references to the literature through 1948. However, the present widespread use of polystyrene is not anticipated at all by the author's statement on page 110, and the use of sulfonated cross-linked polystyrene in the ion exchange field is not mentioned. Some fine work on the mechanism of the cure of phenolics is omitted entirely, and the new development of "cold rubber" is dismissed in three lines.

Treatment of the various fields seems uneven, those in which the author is at home being more completely worked out than the rest. Bearing this in mind, the scientific worker and the technologist interested in how the other fellow does it will find the volume of great help.

K. B. Goldblum

An Introduction to Luminescence of Solids

Humboldt W. Leverenz—John Wiley & Sons, New York (Chapman & Hall, London). 1950. xv+569 pp. $12.00.

This book carefully and thoroughly describes the preparations, properties, and applications of inorganic crystalline materials commonly referred to as phosphors. Detailed recipes for synthesizing, and extensive tables, are presented. The preparation and properties of important cathodoluminescent screens are discussed and their importance in various electronic devices is emphasized. Much of the detailed technical information has not previously been published.

A wordy style of writing, with innumerable qualifying and redundant phrases, significantly lengthens the book. Otherwise, the presentation is good on the empirical work but rather weak on theory. The text is adequately supplemented by 150 excellent plots of phosphor properties and of detailed schematic diagrams of possible mechanisms of luminescence. Formula, author, and subject indexes and a bibliography of 750 references are included.

Although presented as a general introductory text on luminescent solids for nonspecialists in the field, the book seems, rather, a good reference handbook for technicians, engineers, and scientists actively working on the preparation and applications of phosphors.

Ferd E. Williams

Colloid Science (Vol. II: Reversible Systems)

Edited by H. R. Kruyt (Translated by L. C. Jackson)—Elsevier Publishing Co., New York. 1949. xix+753 pp. $11.50.

The second of two volumes written in Holland under the editorship of H. R. Kruyt on the science of colloids was the first to reach publication. The authors of this collective work start with the premise that colloidal systems in the broadest sense are characterized by the possession of large kinetic units. Following this line of thought, stress is laid on the harmony which exists between classical colloid science and the whole field of macromolecules.

The old classification into lyophobic and lyophilic systems has been dropped. By making a distinction between reversible and irreversible systems, a thermodynamically definable difference in stability becomes a basis for classification of colloids. The authors feel that such a classification is more logical than the old one, and this reviewer is inclined to agree. The present volume deals with the reversible systems; Volume I covers the irreversible systems.

The style of presentation, lucid explanations, and ample treatment, including many experimental data, make this a valuable addition to the literature on colloids, particularly certain phases on which much of the original literature is not readily accessible in English. Specific examples are used throughout the book to illustrate some general phenomena; a conscientious effort apparently has been made to select only those in which the phenomena are clearly disclosed or have been studied in greatest detail.

While the book probably has lost nothing of real scientific value in translation, it is to be regretted that terms in common usage in English were not employed in place of certain more or less literal translations from the Dutch.

R. W. Martin

The Anatomy of Mathematics

R. B. Kershner and L. R. Wilcox—Ronald Press, New York. 1950. 416 pp. $6.00.

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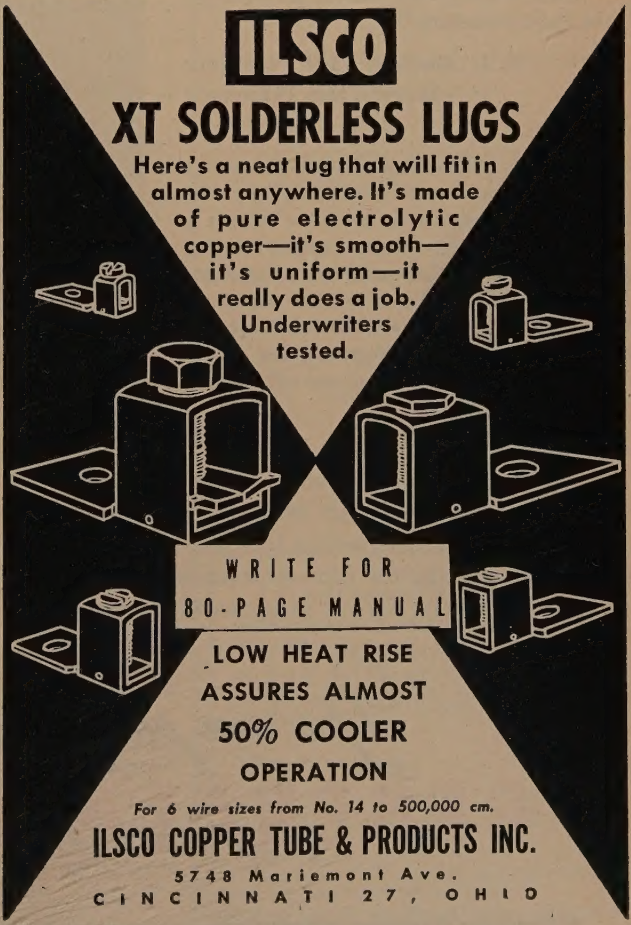

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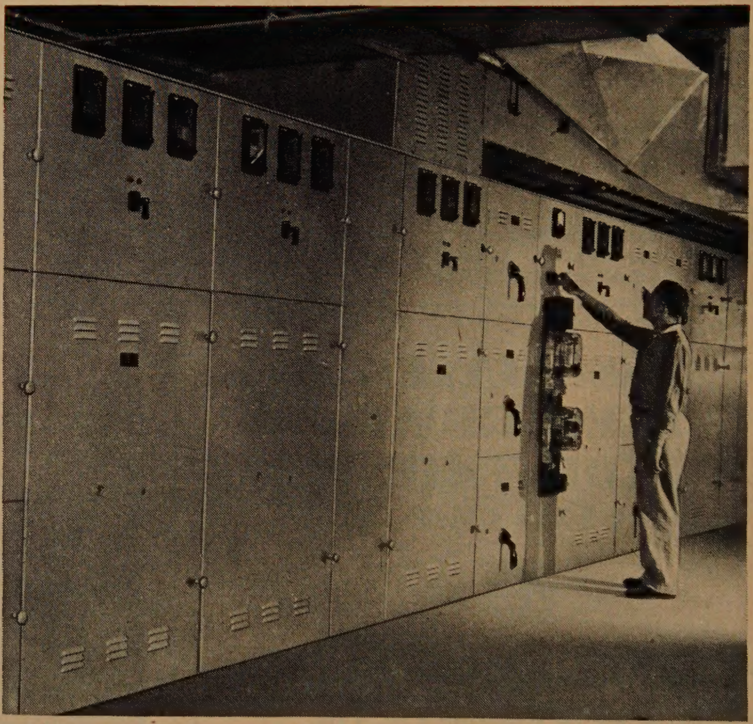

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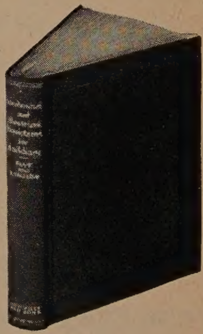

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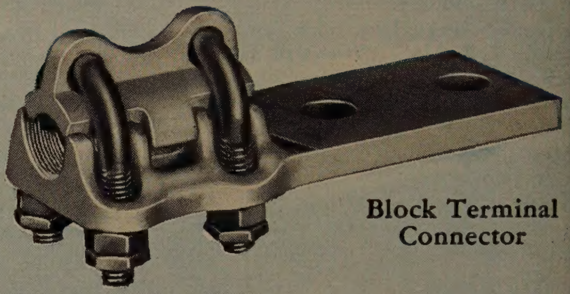

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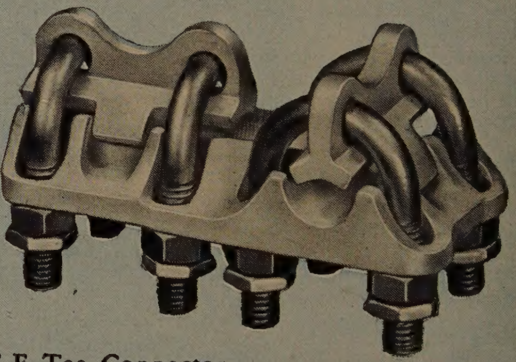

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